Emissions Reference Guide & Standards:
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Emissions Standards: U.S.A.
On-Highway Diesel Truck And Bus Engines

Applicability and Test Cycles

The following emission standards apply to new diesel engines used in heavy-duty highway vehicles. The current federal definition of a compression-ignition (diesel) engine is based on the engine cycle, rather than the ignition mechanism, with the presence of a throttle as an indicator to distinguish between diesel-cycle and otto-cycle operation. Regulating power by controlling the fuel supply in lieu of a throttle corresponds with lean combustion and the diesel-cycle operation (this allows the possibility that a natural gas-fueled engine equipped with a sparkplug is considered a compression-ignition engine).

Heavy-duty vehicles are defined as vehicles of GVWR (gross vehicle weight rating) of above 8,500 lbs in the federal jurisdiction and above 14,000 lbs in California (model year 1995 and later). Diesel engines used in heavy-duty vehicles are further divided into service classes by GVWR, as follows.

- Light heavy-duty diesel engines: 8,500 < LHDDE < 19,500 (14,000 < LHDDE < 19,500 in California, 1995+).
- Medium heavy-duty diesel engines: 19,500 ≤ MHDDE ≤ 33,000.
- Heavy heavy-duty diesel engines (including urban bus): HHDDE > 33,000.

Under the federal light-duty Tier 2 regulation (phased-in beginning 2004) vehicles of GVWR up to 10,000 lbs used for personal transportation have been re-classified as "medium-duty passenger vehicles" (MDPV - primarily larger SUVs and passenger vans) and are subject to the light-duty vehicle legislation. Therefore, the same diesel engine model used for the 8,500 - 10,000 lbs vehicle category may be classified as either light- or heavy-duty and certified to different standards, depending on the application.

Current federal regulations do not require that complete heavy-duty diesel vehicles be chassis certified, instead requiring certification of their engines (as an option, complete heavy-duty diesel vehicles under 14,000 lbs can be chassis certified). Consequently, the basic standards are expressed in g/bhp·hr and require emission testing over the Transient FTP engine dynamometer cycle (however, chassis certification may be required for complete heavy-duty gasoline vehicles with pertinent emission standards expressed in g/mile).

Additional emission testing requirements, first introduced in 1998, include the following:

- **Supplemental Emission Test (SET):** A steady-state test to ensure that heavy-duty engine emissions are controlled during steady-state type driving, such as a line-haul truck operating on a freeway. SET emission limits are numerically equal to the FTP limits.
- **Not-to-Exceed (NTE) testing:** Driving of any type that could occur within the bounds of a pre-defined NTE control area, including operation under steady-state or transient conditions and under varying ambient conditions. NTE emission limits are typically higher than the FTP limits.

These tests were introduced for most signees of the 1998 Consent Decrees between the EPA and engine manufacturers for the period 1998 - 2004. Federal regulations require the supplemental testing from all engine manufacturers effective 2007. In California, the tests are required for all engines effective model year 2005.

Model Year 1987-2003

Model year 1988-2003 US federal (EPA) and 1987-2003 California (ARB) emission standards for heavy-duty diesel truck and bus engines are summarized in the tables 1 and 2. Applicable to the 1994 and following year standards, sulfur content in the certification fuel has been reduced to 500 ppm wt.

Useful Life and Warranty Periods. Compliance with emission standards has to be demonstrated over the useful life of the engine, which was adopted as follows (federal & California):

- LHDDE — 8 years/110,000 miles (whichever occurs first).
- MHDDE — 8 years/185,000 miles.
- HHDDE — 8 years/290,000 miles.

Federal useful life requirements were later increased to 10 years, with no change to the above mileage numbers, for the urban bus PM standard (1994+) and for the NO_x standard (1998+).

Table 1
EPA Emission Standards for Heavy-Duty Diesel Engines, g/bhp·hr

Year	HC	CO	NO_x	PM
Heavy-Duty Diesel Truck Engines				
1988	1.3	15.5	10.7	0.60
1990	1.3	15.5	6.0	0.60
1991	1.3	15.5	5.0	0.25
1994	1.3	15.5	5.0	0.10
1998	1.3	15.5	4.0	0.10
Urban Bus Engines				
1991	1.3	15.5	5.0	0.25
1993	1.3	15.5	5.0	0.10
1994	1.3	15.5	5.0	0.07
1996	1.3	15.5	5.0	0.05*
1998	1.3	15.5	4.0	0.05*
* - in-use PM standard 0.07				

Table 2 California Emission Standards for Heavy-Duty Diesel Engines, g/bhp·hr					
Year	NMHC	THC	CO	NO_x	PM
Heavy-Duty Diesel Truck Engines					
1987	-	1.3	15.5	6.0	0.60
1991	1.2	1.3	15.5	5.0	0.25
1994	1.2	1.3	15.5	5.0	0.10
Urban Bus Engines					
1991	1.2	1.3	15.5	5.0	0.10
1994	1.2	1.3	15.5	5.0	0.07
1996	1.2	1.3	15.5	4.0	0.05

The emission warranty period is 5 years/100,000 miles (5 years/100,000 miles/3,000 hours in California), but no less than the basic mechanical warranty for the engine family.

Clean Fuel Fleet Program. Table 3 shows a voluntary Clean Fuel Fleet (CFF) emission standard. It is a federal standard that applies to 1998-2003 model year engines, both CI and SI, over 8,500 lbs GVWR. In addition to the CFF standard, vehicles must meet applicable conventional standards for other pollutants.

Table 3 Clean Fuel Fleet Program for Heavy-Duty SI and CI Engines, g/bhp·hr				
Category*	CO	$NMHC+NO_x$	PM	HCHO
LEV (Federal Fuel)		3.8		
LEV (California Fuel)		3.5		
ILEV	14.4	2.5		0.050
ULEV	7.2	2.5	0.05	0.025
ZLEV	0	0	0	0
* LEV - low emission vehicle; ILEV - inherently low emission vehicle; ULEV - ultra low emission vehicle; ZEV - zero emission vehicle				

Model Year 2004 and Later

In October 1997, EPA adopted new emission standards for model year 2004 and later heavy-duty diesel truck and bus engines. These standards reflects the provisions of the Statement of Principles (SOP) signed in 1995 by the EPA, California ARB, and the manufacturers of heavy-duty diesel engines. The goal was to reduce NO_x emissions from highway heavy-duty engines to levels approximately 2.0 g/bhp·hr beginning in 2004. Manufacturers have the flexibility to certify their engines to one of the two options shown in Table 4.

Table 4 EPA Emission Standards for MY 2004 and Later HD Diesel Engines, g/bhp·hr		
Option	$NMHC + NO_x$	NMHC
1	2.4	n/a
2	2.5	0.5

All emission standards other than NMHC and NO_x applying to 1998 and later model year heavy duty engines (Table 1) will continue at their 1998 levels.

EPA established revised useful engine lives, with significantly extended requirements for the heavy heavy-duty diesel engine service class, as follows:

- LHDDE — 110,000 miles/10 years.
- MHDDE — 185,000 miles/10 years.
- HHDDE — 435,000 miles/10 years/22,000 hours.

The emission warranty remains at 5 years/100,000 miles.

With the exception of turbocharged and supercharged diesel fueled engines, discharge of crankcase emissions is not allowed for any new 2004 or later model year engines.

The federal 2004 standards for highway trucks are harmonized with California standards, with the intent that manufacturers can use a single engine or machine design for both markets. However, California certifications for model years 2005-2007 additionally require SET testing, and NTE limits of 1.25 × FTP standards. California also adopted more stringent standards for MY 2004-2006 engines for public urban bus fleets.

Consent Decrees. In October 1998, a court settlement was reached between the EPA, Department of Justice, California ARB and engine manufacturers (Caterpillar, Cummins, Detroit Diesel, Volvo, Mack Trucks/Renault and Navistar) over the issue of high NO_x emissions from heavy-duty diesel engines during certain driving modes. Since the early 1990's, the manufacturers used engine control software that caused engines to switch to a more fuel efficient (but higher NO_x) driving mode during steady highway cruising. The EPA considered this engine control strategy an illegal "emission defeat device."

Provisions of the Consent Decree included the following:

- Civil penalties for engine manufacturers and requirements to allocate funds for pollution research.
- Upgrading existing engines to lower NO_x emissions.
- Supplemental Emission Test (steady-state) with a limit equal to the FTP standard and NTE limits of 1.25 × FTP (with the exception of Navistar).
- Meeting the 2004 emission standards by October 2002, 15 months ahead of time.

Model Year 2007 and Later

On December 21, 2000 the EPA signed emission standards for model year 2007 and later heavy-duty highway engines (the California ARB adopted virtually identical 2007 heavy-duty

engine standards in October 2001). The rule includes two components: (1) emission standards, and (2) diesel fuel regulations.

The first component of the regulation introduces new, very stringent emission standards, as follows:

- PM — 0.01 g/bhp-hr.
- NO_x — 0.20 g/bhp-hr.
- NMHC — 0.14 g/bhp-hr.

The PM emission standard will take full effect in the 2007 heavy-duty engine model year. The NO_x and NMHC standards will be phased in for diesel engines between 2007 and 2010. The phase-in would be on a percent-of-sales basis: 50% from 2007 to 2009 and 100% in 2010 (gasoline engines are subject to these standards based on a phase-in requiring 50% compliance in 2008 and 100% compliance in 2009). Very few engines meeting the 0.20 g/bhp-hr NO_x requirement will actually appear before 2010. In 2007, most manufacturers opted instead to meet a Family Emission Limit (FEL) around 1.2-1.5 g/bhp-hr NO_x for most of their engines with a few manufacturers still certifying some of their engines as high as 2.5 g/bhp-hr NO_x+NMHC.

In addition to transient FTP testing, emission certification requirements also include:

- SET test, with limits equal to the FTP standards, and
- NTE testing with limits of 1.5 × FTP standards for engines meeting a NO_x FEL of 1.5 g/bhp-hr or less and 1.25 × FTP standards. for engines with a NO_x FEL higher than 1.5 g/bhp-hr.

Effective for the 2007 model year, the regulation maintains the earlier crankcase emission control exception for turbocharged heavy-duty diesel fueled engines but requires that if they are emitted to the atmosphere, they be added to the exhaust emissions during all testing. In this case, the deterioration of crankcase emissions must also be accounted for in exhaust deterioration factors.

The diesel fuel regulation limits the sulfur content in on-highway diesel fuel to 15 ppm (wt.), down from the previous 500 ppm. Refiners will be required to start producing the 15 ppm S fuel beginning June 1, 2006. At the terminal level, highway diesel fuel sold as low sulfur fuel must meet the 15 ppm sulfur standard as of July 15, 2006. For retail stations and wholesale purchasers, highway diesel fuel sold as low sulfur fuel must meet the 15 ppm sulfur standard by September 1, 2006.

Refiners can also take advantage of a temporary compliance option that will allow them to continue producing 500 ppm fuel in 20% of the volume of diesel fuel they produce until December 31, 2009. In addition, refiners can participate in an averaging, banking and trading program with other refiners in their geographic area.

Ultra low sulfur diesel fuel has been introduced as a "technology enabler" to pave the way for advanced, sulfur-intolerant exhaust emission control technologies, such as catalytic diesel particulate filters and NO_x catalysts, which will be necessary to meet the 2007 emission standards.

The EPA estimates the cost of reducing the sulfur content of diesel fuel will result in a fuel price increase of approximately 4.5 to 5 cents per gallon. The EPA also estimates that the new emission standards will cause an increase in vehicle costs between $1,200 to $1,900 (for comparison, new heavy-duty trucks typically cost up to $150,000 and buses up to $250,000).

Emissions Standards: U.S.A.
Off-Highway Engines

Background

Tier 1-3 Standards. The first federal standards (Tier 1) for new nonroad (or off-road) diesel engines were adopted in 1994 for engines over 37 kW (50 hp), to be phased-in from 1996 to 2000. In 1996, a Statement of Principles (SOP) pertaining to nonroad diesel engines was signed between EPA, California ARB and engine makers (including Caterpillar, Cummins, Deere, Detroit Diesel, Deutz, Isuzu, Komatsu, Kubota, Mitsubishi, Navistar, New Holland, Wis-Con, and Yanmar). On August 27, 1998, the EPA signed the final rule reflecting the provisions of the SOP. The 1998 regulation introduced Tier 1 standards for equipment under 37 kW (50 hp) and increasingly more stringent Tier 2 and Tier 3 standards for all equipment with phase-in schedules from 2000 to 2008. The Tier 1-3 standards are met through advanced engine design, with no or only limited use of exhaust gas aftertreatment (oxidation catalysts). Tier 3 standards for NO_x+HC are similar in stringency to the 2004 standards for highway engines, however Tier 3 standards for PM were never adopted.

Tier 4 Standards. On May 11, 2004, the EPA signed the final rule introducing Tier 4 emission standards, which are to be phased-in over the period of 2008-2015 *[69 FR 38957-39273, 29 Jun 2004]*. The Tier 4 standards require that emissions of PM and NO_x be further reduced by about 90%. Such emission reductions can be achieved through the use of control technologies — including advanced exhaust gas aftertreatment — similar to those required by the 2007-2010 standards for highway engines.

Nonroad Diesel Fuel. At the Tier 1-3 stage, the sulfur content in nonroad diesel fuels was not limited by environmental regulations. The oil industry specification was 0.5% (wt., max), with the average in-use sulfur level of about 0.3% = 3,000 ppm. To enable sulfur-sensitive control technologies in

Tier 4 engines — such as catalytic particulate filters and NO_x adsorbers — the EPA mandated reductions in sulfur content in nonroad diesel fuels, as follows:

- 500 ppm effective June 2007 for nonroad, locomotive and marine (NRLM) diesel fuels.
- 15 ppm (ultra-low sulfur diesel) effective June 2010 for nonroad fuel, and June 2012 for locomotive and marine fuels.

California. In most cases, federal nonroad regulations also apply in California, whose authority to set emission standards for new nonroad engines is limited. The federal Clean Air Act Amendments of 1990 (CAA) preempt California's authority to control emissions from new farm and construction equipment under 175 hp *[CAA Section 209(e)(1)(A)]* and require California to receive authorization from the federal EPA for controls over other off-road sources *[CAA Section 209 (e)(2)(A)]*.

The US nonroad emission standards are harmonized to a certain degree with European nonroad emission standards.

EPA emission standards for nonroad diesel engines are published in the US Code of Federal Regulations, Title 40, Part 89 *[40 CFR Part 89]*.

Applicability

The nonroad standards cover mobile *nonroad diesel engines* of all sizes used in a wide range of construction, agricultural and industrial equipment. The EPA definition of the *nonroad engine* is based on the principle of mobility/portability, and includes engines installed on (1) self-propelled equipment, (2) on equipment that is propelled while performing its function, or (3) on equipment that is portable or transportable, as indicated by the presence of wheels, skids, carrying handles, dolly, trailer, or platform *[40 CFR 1068.30]*. In other words, nonroad engines are all internal combustion engines except motor vehicle (highway) engines, stationary engines (or engines that remain at one location for more than 12 months), engines used solely for competition, or engines used in aircraft.

Effective May 14, 2003, the definition of nonroad engines was changed to also include all diesel powered engines — including stationary ones — used in agricultural operations in California. This change applies only to engines sold in the state of California; stationary engines sold in other states are not classified as nonroad engines.

The nonroad diesel emission regulations are not applicable to all nonroad diesel engines. Exempted are the following nonroad engine categories:

- Engines used in railway locomotives; those are subject to separate EPA regulations.
- Engines used in marine vessels, also covered by separate EPA regulations. Marine engines below 37 kW (50 hp) are subject to Tier 1-2 — but not Tier 4 — nonroad standards. Certain marine engines that are exempted from marine standards may be subject to nonroad regulations.
- Engines used in underground mining equipment. Diesel emissions and air quality in mines are regulated by the Mine Safety and Health Administration (MSHA).
- Hobby engines (below 50 cm^3 per cylinder).

Examples of regulated applications include farm tractors, excavators, bulldozers, wheel loaders, backhoe loaders, road graders, diesel lawn tractors, logging equipment, portable generators, skid steer loaders, or forklifts.

A new definition of a compression-ignition (diesel) engine is used in the regulatory language since the 1998 rule, that is consistent with definitions established for highway engines. The definition focuses on the engine cycle, rather than the ignition mechanism, with the presence of a throttle as an indicator to distinguish between diesel-cycle and otto-cycle operation. Regulating power by controlling the fuel supply in lieu of a throttle corresponds with lean combustion and diesel-cycle operation. This language allows the possibility that a natural gas-fueled engine equipped with a sparkplug is considered a compression-ignition engine.

Tier 1-3 Emission Standards

The 1998 nonroad engine regulations are structured as a 3-tiered progression. Each tier involves a phase in (by horsepower rating) over several years. Tier 1 standards were phased-in from 1996 to 2000. The more stringent Tier 2 standards take effect from 2001 to 2006, and yet more stringent Tier 3 standards phase-in from 2006 to 2008 (Tier 3 standards apply only for engines from 37-560 kW).

Tier 1-3 emissions standards are listed in Table 1. Nonroad regulations are in the metric system of units, with all standards expressed in grams of pollutant per kWh.

Manufacturers who signed the 1998 Consent Decrees with the EPA may be required to meet the Tier 3 standards one year ahead of schedule (i.e. beginning in 2005).

Voluntary, more stringent emission standards that manufacturers could use to earn a designation of "Blue Sky Series" engines (applicable to Tier 1-3 certifications) are listed in Table 2.

Engines of all sizes must also meet smoke standards of 20/15/50% opacity at acceleration/lug/peak modes, respectively.

The regulations include several other provisions, such as averaging, banking and trading of emission credits and maximum "family emission limits" (FEL) for emission averaging.

Table 1 EPA Tier 1-3 Nonroad Diesel Engine Emission Standards, g/kWh (g/bhp·hr)							
Engine Power	**Tier**	**Year**	**CO**	**HC**	**NMHC+NO_x**	**NO_x**	**PM**
kW < 8 (hp < 11)	Tier 1	2000	8.0 (6.0)	-	10.5 (7.8)	-	1.0 (0.75)
	Tier 2	2005	8.0 (6.0)	-	7.5 (5.6)	-	0.8 (0.6)
8 ≤ kW < 19 (11 ≤ hp < 25)	Tier 1	2000	6.6 (4.9)	-	9.5 (7.1)	-	0.8 (0.6)
	Tier 2	2005	6.6 (4.9)	-	7.5 (5.6)	-	0.8 (0.6)
19≤ kW < 37 (25 ≤ hp < 50)	Tier 1	1999	5.5 (4.1)	-	9.5 (7.1)	-	0.8 (0.6)
	Tier 2	2004	5.5 (4.1)	-	7.5 (5.6)	-	0.6 (0.45)
37 ≤ kW < 75 (50 ≤ hp < 100)	Tier 1	1998	-	-	-	9.2 (6.9)	-
	Tier 2	2004	5.0 (3.7)	-	7.5 (5.6)	-	0.4 (0.3)
	Tier 3	2008	5.0 (3.7)	-	4.7 (3.5)	-	-†
75 ≤ kW < 130 (100 ≤ hp < 175)	Tier 1	1997	-	-	-	9.2 (6.9)	-
	Tier 2	2003	5.0 (3.7)	-	6.6 (4.9)	-	0.3 (0.22)
	Tier 3	2007	5.0 (3.7)	-	4.0 (3.0)	-	-†
130 ≤ kW < 225 (175 ≤ hp < 300)	Tier 1	1996	11.4 (8.5)	1.3 (1.0)	-	9.2 (6.9)	0.54 (0.4)
	Tier 2	2003	3.5 (2.6)	-	6.6 (4.9)	-	0.2 (0.15)
	Tier 3	2006	3.5 (2.6)	-	4.0 (3.0)	-	-†
225 ≤ kW < 450 (300 ≤ hp < 600)	Tier 1	1996	11.4 (8.5)	1.3 (1.0)	-	9.2 (6.9)	0.54 (0.4)
	Tier 2	2001	3.5 (2.6)	-	6.4 (4.8)	-	0.2 (0.15)
	Tier 3	2006	3.5 (2.6)	-	4.0 (3.0)	-	-†
450 ≤ kW < 560 (600 ≤ hp < 750)	Tier 1	1996	11.4 (8.5)	1.3 (1.0)	-	9.2 (6.9)	0.54 (0.4)
	Tier 2	2002	3.5 (2.6)	-	6.4 (4.8)	-	0.2 (0.15)
	Tier 3	2006	3.5 (2.6)	-	4.0 (3.0)	-	-†
kW ≥ 560 (hp ≥ 750)	Tier 1	2000	11.4 (8.5)	1.3 (1.0)	-	9.2 (6.9)	0.54 (0.4)
	Tier 2	2006	3.5 (2.6)	-	6.4 (4.8)	-	0.2 (0.15)
† Not adopted, engines must meet Tier 2 PM standard.							

Table 2 EPA Voluntary Emission Standards for Nonroad Diesel Engines, g/kWh (g/bhp·hr)		
Rated Power (kW)	**NMHC+NO_x**	**PM**
kW < 8	4.6 (3.4)	0.48 (0.36)
8 ≤ kW <19	4.5 (3.4)	0.48 (0.36)
19 ≤ kW <37	4.5 (3.4)	0.36 (0.27)
37 ≤ kW < 75	4.7 (3.5)	0.24 (0.18)
75 ≤ kW <130	4.0 (3.0)	0.18 (0.13)
130 ≤ kW < 560	4.0 (3.0)	0.12 (0.09)
kW ≥ 560	3.8 (2.8)	0.12 (0.09)

Tier 4 Emission Standards

The Tier 4 emission standards — to be phased-in from 2008-2015 — introduce substantial reductions of NO_x (for engines above 56 kW) and PM (above 19 kW), as well as more stringent HC limits. CO emission limits remain unchanged from the Tier 2-3 stage.

Engines up to 560 kW. Tier 4 emission standards for engines up to 560 kW are listed in Table 3.

In engines of 56-560 kW rated power, the NO_x and HC standards are phased-in over a few year period, as indicated in the notes to Table 3. The initial standards (PM compliance) are sometimes referred to as the 'interim Tier 4' (or 'Tier 4i'), 'transitional Tier 4' or 'Tier 4 A', while the final standards (NO_x/HC compliance) are sometimes referred to as 'Tier 4 B'.

As an alternative to introducing the required percentage of Tier 4 compliant engines, manufacturers may certify all their engines to an *alternative NO_x limit* in each model year during the phase-in period. These alternative NO_x standards are:

- Engines 56-130 kW:
  - Option 1: NO_x = 2.3 g/kWh = 1.7 g/bhp-hr (Tier 2 credits used to comply, MY 2012-2013).
  - Option 2: NO_x = 3.4 g/kWh = 2.5 g/bhp-hr (no Tier 2 credits claimed, MY 2012-2014).
- Engines 130-560 kW: NO_x = 2.0 g/kWh = 1.5 g/bhp-hr (MY 2011-2013).

Engines Above 560 kW. Tier 4 emission standards for engines above 560 kW are listed in Table 4. The 2011 standards are sometimes referred to as 'transitional Tier 4', while the 2015 limits represent final Tier 4 standards.

Other Provisions. Existing Tier 2-3 smoke opacity standards and procedures continue to apply in some engines. Exempted from smoke emission standards are engines certified to PM emission standards at or below 0.07 g/kWh (because an engine of such low PM level has inherently low smoke emission).

The Tier 4 regulation does not require closed crankcase

Table 3
Tier 4 Emission Standards — Engines up to 560 kW, g/kWh (g/bhp-hr)

Engine Power	Year	CO	NMHC	NMHC+NO_x	NO_x	PM
kW < 8 (hp < 11)	2008	8.0 (6.0)	-	7.5 (5.6)	-	0.4[a] (0.3)
8 ≤ kW < 19 (11 ≤ hp < 25)	2008	6.6 (4.9)	-	7.5 (5.6)	-	0.4 (0.3)
19 ≤ kW < 37 (25 ≤ hp < 50)	2008	5.5 (4.1)	-	7.5 (5.6)	-	0.3 (0.22)
	2013	5.5 (4.1)	-	4.7 (3.5)	-	0.03 (0.022)
37 ≤ kW < 56 (50 ≤ hp < 75)	2008	5.0 (3.7)	-	4.7 (3.5)	-	0.3[b] (0.22)
	2013	5.0 (3.7)	-	4.7 (3.5)	-	0.03 (0.022)
56 ≤ kW < 130 (75 ≤ hp < 175)	2012-2014[c]	5.0 (3.7)	0.19 (0.14)	-	0.40 (0.30)	0.02 (0.015)
130 ≤ kW ≤ 560 (175 ≤ hp ≤ 750)	2011-2014[d]	3.5 (2.6)	0.19 (0.14)	-	0.40 (0.30)	0.02 (0.015)

a - hand-startable, air-cooled, DI engines may be certified to Tier 2 standards through 2009 and to an optional PM standard of 0.6 g/kWh starting in 2010
b - 0.4 g/kWh (Tier 2) if manufacturer complies with the 0.03 g/kWh standard from 2012
c - PM/CO: full compliance from 2012; NO_x/HC: Option 1 (if banked Tier 2 credits used)—50% engines must comply in 2012-2013; Option 2 (if no Tier 2 credits claimed)—25% engines must comply in 2012-2014, with full compliance from 2014.12.31
d - PM/CO: full compliance from 2011; NO_x/HC: 50% engines must comply in 2011-2013

Table 4
Tier 4 Emission Standards — Engines Above 560 kW, g/kWh (g/bhp-hr)

Year	Category	CO	NMHC	NO_x	PM
2011	Generator sets > 900 kW	3.5 (2.6)	0.40 (0.30)	0.67 (0.50)	0.10 (0.075)
	All engines except gensets > 900 kW	3.5 (2.6)	0.40 (0.30)	3.5 (2.6)	0.10 (0.075)
2015	Generator sets	3.5 (2.6)	0.19 (0.14)	0.67 (0.50)	0.03 (0.022)
	All engines except gensets	3.5 (2.6)	0.19 (0.14)	3.5 (2.6)	0.04 (0.03)

ventilation in nonroad engines. However, in engines with open crankcases, crankcase emissions must be measured and added to exhaust emissions in assessing compliance.

Similarly to earlier standards, the Tier 4 regulation includes such provisions as averaging, banking and trading of emission credits and FEL limits for emission averaging.

Test Cycles and Fuels

Nonroad engine emissions are measured on a steady-state test cycle that is nominally the same as the ISO 8178 C1, 8-mode steady-state test cycle. Other ISO 8178 test cycles are allowed for selected applications, such as constant-speed engines (D2 5-mode cycle), variable-speed engines rated under 19 kW (G2 cycle), and marine engines (E3 cycle).

Transient Testing. Tier 4 standards have to be met over both the steady-state test and the nonroad transient cycle, NRTC. The transient testing requirements begin with MY 2013 for engines below 56 kW, in 2012 for 56-130 kW, and in 2011 for 130-560 kW engines. Engines above 560 kW are not tested on the transient test. Also constant-speed, variable-load engines of any power category are not subject to transient testing. The NRTC protocol includes a cold start test. The cold start emissions are weighted at 5% and hot start emissions are weighted at 95% in calculating the final result.

Tier 4 nonroad engines will also have to meet not-to-exceed standards (NTE), which are measured without reference to any specific test schedule. The NTE standards become effective in 2011 for engines above 130 kW; in 2012 for 56-130 kW; and in 2013 for engines below 56 kW. In most engines, the NTE limits are set at 1.25 times the regular standard for each pollutant (in engines certified to NO_x standards below 2.5 g/kWh or PM standards below 0.07 g/kWh, the NTE multiplier is 1.5). The NTE standards apply to engines at the time of certification, as well as in use throughout the useful life of the engine. The purpose of the added testing requirements is to prevent the possibility of "defeating" the test cycle by electronic engine controls and producing off-cycle emissions.

Certification Fuels. Fuels with sulfur levels no greater than 0.2 wt% (2,000 ppm) are used for certification testing of Tier 1-3 engines. From 2011, all Tier 4 engines will be tested using fuels of 7-15 ppm sulfur content. A transition from the 2000 ppm S specification to the 7-15 ppm specification will occur in the 2006-2010 period (see Certification Diesel Fuel).

A change from measuring total hydrocarbons to non-methane hydrocarbons (NMHC) has been introduced in the 1998 rule. Since there is no standardized EPA method for measuring methane in diesel engine exhaust, manufacturers can either use their own procedures to analyze nonmethane hydrocarbons or measure total hydrocarbons and subtract 2% from the measured hydrocarbon mass to correct for methane.

Engine Useful Life

Emission standards listed in the tables must be met over the entire useful life of the engine. EPA requires the application of deterioration factors (DFs) to all engines covered by the rule. The DF is a factor applied to the certification emission test data to represent emissions at the end of the useful life of the engine.

Table 5 Useful Life and Recall Testing Periods					
Power Rating	Rated Engine Speed	Useful Life		Recall Testing Period	
		hours	years	hours	years
< 19 kW	all	3000	5	2250	4
19-37 kW	constant speed engines ≥3000 rpm	3000	5	2250	4
	all others	5000	7	3750	5
>37 kW	all	8000	10	6000	7

The engine useful life and the in-use testing liability period, as defined by the EPA for emission testing purposes, are listed in Table 5 for different engine categories. The Tier 4 rule maintains the same engine useful life periods.

Environmental Benefit and Cost

1998 Regulation. At the time of signing the 1998 rule, the EPA estimated that by 2010 NO_x emissions would be reduced by about a million tons per year, the equivalent of taking 35 million passenger cars off the road.

The costs of meeting the emission standards were expected to add under 1% to the purchase price of typical new nonroad diesel equipment, although for some equipment the standards may cause price increases on the order of 2-3%. The program was expected to cost about $600 per ton of NO_x reduced.

Tier 4 Regulation. When the full inventory of older nonroad engines are replaced by Tier 4 engines, annual emission reductions are estimated at 738,000 tons of NO_x and 129,000 tons of PM. By 2030, 12,000 premature deaths would be prevented annually due to the implementation of the proposed standards.

The estimated costs for added emission controls for the vast majority of equipment was estimated at 1-3% as a fraction of total equipment price. For example, for a 175 hp bulldozer that costs approximately $230,000 it would cost up to $6,900 to add the advanced emission controls and to design the bulldozer to accommodate the modified engine.

EPA estimated that the average cost increase for 15 ppm S fuel will be 7 cents per gallon. This figure would be reduced to 4 cents by anticipated savings in maintenance costs due to low sulfur diesel.

Emissions Standards: U.S.A.
Stationary Diesel Engines (NSPS)

Background

The US Clean Air Act requires that new source performance standards (NSPS) be established to control emissions from new stationary sources [CAA, Section 111(b)]. An NSPS requires these sources to control emissions to the level achievable by *best demonstrated technology* (BDT), considering costs and any non-air quality health and environmental impacts and energy requirements. New sources are defined as those whose construction, reconstruction, or modification begins after a standard for them is proposed.

In 1979, the EPA proposed NSPS standards for stationary engines, but they were never finalized. In the absence of federal regulations, emissions from stationary engines gradually became subject to a complex system of state and/or local regulations and permit policies, such as those in California, Texas, or the NESCAUM states.

The NSPS standards for stationary engines were adopted through several regulations. The following are some of the important regulatory steps:

- On July 11, 2006, the EPA promulgated emission regulations for stationary diesel engines, which require that most new stationary diesel engines meet the Tier 1-4 emission standards for mobile nonroad engines.
- On January 18, 2008, EPA promulgated emission standards for stationary spark ignition (SI) internal combustion engines.
- On May 21, 2010, the EPA proposed amendments to the 2006 rule to strengthen the standards for engines of 10-30 liters per cylinder to levels required by marine engines of the same sizes. The proposed rule would also align emission standards for engines above 30 liters per cylinder with those for marine engines. The proposal also includes minor revisions to the SI engine requirements.

In addition to the NSPS standards, emission requirements for certain categories of new stationary engines are also specified by the National Emission Standards for Hazardous Air Pollutants (NESHAP). Since the NSPS and NESHAP emis-

sion standards were adopted through a number of rules — in some cases prompted by court actions against EPA by various environmental or industry groups — the structure of the regulations is complex. This article covers the NSPS standards for new diesel engines (SI engines are also regulated, but not covered by this summary). Also available is a summary of NESHAP requirements for existing stationary engines.

Emission regulations for stationary diesel engines are published in Title 40 Chapter I, Part 60 of the Code of Federal Regulations (CFR).

Applicability

The NSPS standards apply to stationary compression ignition internal combustion engines (CI ICE) as defined below:

- A *stationary internal combustion engine* means any internal combustion engine, except combustion turbines, that converts heat energy into mechanical work and is not mobile. Stationary ICE differ from mobile ICE in that a stationary internal combustion engine is not a nonroad engine as defined at 40 CFR 1068.30, and is not used to propel a motor vehicle or a vehicle used solely for competition. Stationary ICE include reciprocating ICE, rotary ICE, and other ICE, except combustion turbines.

- A *compression ignition engine* means a type of stationary internal combustion engine that is not a spark ignition (SI) engine. An SI engine means a gasoline, natural gas, or liquefied petroleum gas fueled engine or any other type of engine with a spark plug (or other sparking device) and with operating characteristics significantly similar to the theoretical Otto combustion cycle. Spark ignition engines usually use a throttle to regulate intake air flow to control power during normal operation. Dual fuel engines in which a liquid fuel (typically diesel fuel) is used for CI and gaseous fuel (typically natural gas) is used as the primary fuel at an annual average ratio of less than 2 parts diesel fuel to 100 parts total fuel on an energy equivalent basis are SI engines.

Typical examples are stationary diesel engines used to generate electricity and operate compressors and pumps at power and manufacturing plants. The rule also covers stationary engines that are used in emergencies, including emergency generators of electricity and water pumps for fire and flood control. The emission standards apply to new, modified, and reconstructed stationary diesel engines (i.e., existing in-use engines are not affected).

Timing. The emission standards apply to engines whose construction, modification or reconstruction commenced after July 11, 2005 — the date the proposed rule was published in the Federal Register. Compliance with Tier 1 standards is delayed to April 1, 2006 for non-fire pump engines and to July 1, 2006 for fire pump engines.

Emission Standards

The standards apply to emissions of NO_x, PM, CO, and NMHC. They are expressed in units of g/kWh and smoke standards as a percentage. No new emission limits were developed for stationary engines. Rather, the engines are required to meet emission standards for various types of mobile engines, depending on the engine size and application:

i. Engines of displacement below 10 liters per cylinder must meet Tier 1 through Tier 4 emission standards for mobile nonroad diesel engines (almost all stationary engines in the USA belong to this size category). Engines used only for emergencies, for example stand-by generator sets, are exempted from the most stringent Tier 4 emission requirements.

ii. Engines of displacement above 10 liters per cylinder must meet emission standards for marine engines.

Two groups of standards have been adopted: (1) for engine manufacturers, and (2) for engine owners/operators. Beginning with model year (MY) 2007, engine manufactures are required to emission certify stationary engines, and so they are responsible for compliance. During the transitional period before the MY 2007, engines can be sold that are not emission certified. In that case, the engine owner/operator is responsible for emission compliance.

Standards for Engine Manufacturers. Emission certification requirements for stationary *non-emergency* diesel engines are summarized in Table 1. From 2007, all stationary engines below 30 liters per cylinder must be certified to the respective standards, as applicable for the model year and maximum engine power (and displacement per cylinder in marine standards).

Table 1
Emission Requirements for Non-Emergency Stationary Engines

Displacement (D)	Power	Year	Emission Certification
D < 10 L per cylinder	≤ 3000 hp	2007+	Nonroad Tier 2/3/4
	> 3000 hp	2007-2010	Nonroad Tier 1
		2011+	Nonroad Tier 2/4
10 ≤ D < 30 L per cylinder	All	2007+	Marine Cat. 2 Tier 2/3/4 (Tier 3/4 proposed)
D ≥ 30 L per cylinder	All	2010-2011	Marine Cat. 3 Tier 1 (proposed)
		2012+	Marine Cat. 3 Tier 2/3 (proposed)

Emission certification requirements also apply to *emergency engines* from 2007, but the certification levels are less stringent:

- Emergency engines that are not fire pump engines must be certified to the standards shown in Table 1, with the exception of standards (including nonroad Tier 4 and marine Category 3 Tier 3) that require "add-on" controls such as diesel particulate filters or NO_x reduction catalysts.

- Emergency fire pump engines must be certified to standards that are generally based on nonroad Tier 1 and Tier 2, with Tier 2 becoming effective around 2008-2011, depending on the engine power category.

The time allowed for maintenance and testing of emergency engines is 100 hours per year.

Standards for Engine Owners/Operators. Depending on the engine category, owners and operators are responsible for emission compliance as follows:

- Engines < 30 liters per cylinder.
    - Pre-2007:
        - Engines < 10 liters per cylinder must meet nonroad Tier 1 emission standards.
        - Engines ≥ 10 liters per cylinder must meet MARPOL Annex VI NO_x limits (Tier 1 marine standards).
    - 2007 and later: owners/operators must buy emission certified engines.
- Engines ≥ 30 liters per cylinder:
    - Under the 2006 rule, owners/operators are required to reduce NO_x emissions by 90%, or alternatively they must limit NO_x to 1.6 g/kWh (1.2 g/hp-hr). Owners/operators are also required to reduce PM emissions by 60%, or alternatively they must limit PM to 0.15 g/kWh (0.11 g/hp-hr).
    - Under the 2010 proposal, engines must be certified to the standards shown in Table 1.

Owners/operators of pre-2007 engines < 30 liters per cylinder can demonstrate compliance by purchasing a certified engine. If a non-certified engine is purchased, compliance may be demonstrated using emission test results from a test conducted on a similar engine; data from the engine manufacturer; data from the control device vendor; or conducting a performance test. If in-use performance test is conducted, the owner would be required to meet not-to-exceed (NTE) emission standards instead of the respective certification emission standards. Pre-2007 engines must meet NTE standards of 1.25 × the applicable certification emission standard. The information which demonstrates engine compliance and the appropriate maintenance records must be kept on site.

Owners/operators of engines ≥ 30 liters per cylinder must conduct an initial performance test to demonstrate emissions compliance (NO_x is measured using EPA Method 7E, PM using EPA Method 5 *[40 CFR part 60 appendix A]*). The NTE standards do not apply to engines ≥ 30 liters per cylinder.

Fuel Program. The affected engines would also have to switch to low sulfur fuels:

- Engines below 30 liters per cylinder:
    - No more than 500 ppm sulfur by October 2007,
    - Ultra-low sulfur diesel (15 ppm sulfur) by October 2010.
- Engines ≥ 30 liters per cylinder: 1,000 ppm sulfur fuel from 2014 (proposed).

These fuel requirements are consistent with those for mobile nonroad engines and marine engines. Some of the fuel quality requirements are delayed in areas of Alaska.

Economic Impact

The EPA estimated that the 2006 rule will affect 81,500 new stationary diesel engines. Emission reductions will occur gradually from 2005 to 2015, with the total nationwide annual costs for the rule to be $57 million in 2015.

The following are EPA estimates of the price increase for the compliant equipment due to the added cost of emission controls (year 2015):

Irrigation systems: 2.3%.

Pumps and compressors: 4.3%.

Generator sets and welding equipment: 10.0%.

Emissions Standards: U.S.A.
Existing Stationary Engines (NESHAP)

Background

The US Environmental Protection Agency (EPA) issued a number of rules to control emissions of *toxic air pollutants* from existing stationary reciprocating internal combustion engines (RICE):

- On June 15, 2004, the EPA issued a rule applicable to several new and existing RICE categories, which included emission standards for certain existing spark ignition (SI) stationary engines.
- On February 17, 2010, the EPA issued a rule to reduce emissions from existing diesel powered stationary engines (compression ignition, CI, engines).
- On August 20, 2010, the EPA issued a rule to reduce emissions from existing gas-fired stationary engines (spark ignition, SI, engines).

- On March 9, 2011, the EPA issued a rule introducing several minor amendments and clarifications to the regulation published on August 20, 2010.

The rules, titled National Emission Standards for Hazardous Air Pollutants (NESHAP) for Reciprocating Internal Combustion Engines, are intended to reduce emissions of toxic air pollutants — such as formaldehyde (HCHO), acetaldehyde, acrolein, methanol and other air toxics — from several categories of previously unregulated stationary engines. The EPA has determined that carbon monoxide (CO) can be often used as an appropriate surrogate for formaldehyde. Since testing for CO emissions has many advantages over testing for emissions of hazardous air pollutants (HAP), most of the emission standards have been finalized in terms of CO as the only regulated pollutant.

The NESHAP standards discussed below are applicable to existing engines. Separate regulations have been adopted to control emissions from new stationary engines.

The NESHAP regulations for stationary engines are published in Title 40, Part 63, Subpart ZZZZ (63.6580) of the Code of Federal Regulations (CFR).

Applicability

The applicability of the emission standards depends on the classification of the source of air toxics emissions. "Major sources" of air toxics are defined as those that emit 10 short tons per year of a single air toxic or 25 short tons per year of a mixture of air toxics. "Area sources" are those sources that are not "major sources".

The NESHAP rules are applicable to "existing" diesel and SI engines, as determined by their date of construction or reconstruction:

- "Area sources" of air toxics emissions: Engines constructed or reconstructed before June 12, 2006.
- "Major sources" of air toxics emissions:
  - Engines ≤ 500 hp constructed or reconstructed before June 12, 2006.
  - Engines > 500 hp constructed or reconstructed before December 19, 2002.

The emission standards apply to engines used for non-emergency purposes.

Emission Standards

The NESHAP standards are expressed as volumetric, dry CO concentrations (ppmvd) at 15% O_2 (with the exception of standards for rich-burn SI engines, expressed as volumetric concentrations of HCHO at 15% O_2). The standards must be met during any operating conditions, except during periods of start-up (of maximum 30 minutes). Emissions are tested at 100% load.

Alternative compliance options are available in certain engine categories, expressed as percentage CO or HCHO emission reductions. These reductions can be achieved by retrofitting engines with such controls as oxidation catalysts.

The standards for stationary diesel engines are listed in the following table.

Table 1
NESHAP Emission Requirements for Stationary Diesel (CI) Engines

Engine Category	Emission Standard	Alternative CO Reduction
Area Sources		
Non-Emergency 300 < hp ≤ 500	49 ppmvd CO	70%
Non-Emergency > 500 hp	23 ppmvd CO	70%
Major Sources		
Non-Emergency 100 ≤ hp ≤ 300	230 ppmvd CO	-
Non-Emergency 300 < hp ≤ 500	49 ppmvd CO	70%
Non-Emergency > 500 hp	23 ppmvd CO	70%

Standards for spark ignition, gas-fired stationary engines are summarized in Table 2. The engine designations indicate two- or four-stroke (2S/4S) lean- or rich-burn (LB/RB) gas engines.

Table 2
NESHAP Emission Requirements for Stationary Gas (SI) Engines

Engine Category	Emission Standard	Alternative CO/HCHO Reduction
Area Sources		
4SLB, Non-Emergency > 500 hp	47 ppmvd CO	93% CO
4SRB, Non-Emergency > 500 hp	2.7 ppmvd HCHO	76% HCHO
Major Sources		
2SLB, Non-Emergency 100 ≤ hp ≤ 500	225 ppmvd CO	-
4SLB, Non-Emergency 100 ≤ hp ≤ 500	47 ppmvd CO	-
4SRB, Non-Emergency 100 ≤ hp ≤ 500	10.3 ppmvd HCHO	-
Landfill/Digester Gas, Non-Emergency 100 ≤ hp ≤ 500	177 ppmvd CO	-
4SRB, Non-Emergency > 500 hp	350 ppmvd HCHO	76% HCHO

Other Provisions

Diesel Fuel. The diesel rule requires the use of ultra-low sulfur diesel fuel for stationary non-emergency engines greater than 300 hp with a displacement of less than 30 liters per cylinder. The regulation will be fully implemented by 2013.

Crankcase Filtration. Stationary engines above 300 hp must be equipped with closed or open crankcase filtration system in order to reduce metallic HAP emissions.

The regulations specify a number of other requirements and provisions, including *work practices* for operators of diesel and SI engines.

Locomotives

Background

US emission standards for railway locomotives apply to newly manufactured, as well as remanufactured railroad locomotives and locomotive engines. The standards have been adopted by the EPA in two regulatory actions:

- *Tier 0-2 standards:* The first emission regulation for railroad locomotives was adopted on 17 December 1997 [63 FR 18997-19084, 16 Apr 1998]. The rulemaking, which became effective from 2000, applies to locomotives originally manufactured from 1973, any time they are manufactured or remanufactured. Tier 0-2 standards are met though engine design methods, without the use of exhaust gas aftertreatment.

- *Tier 3-4 standards:* A regulation signed on 14 March 2008 introduced more stringent emission requirements [73 FR 88 25098-25352, 6 May 2008]. Tier 3 standards, to be met by engine design methods, become effective from 2011/12. Tier 4 standards, which are expected to require exhaust gas aftertreatment technologies, become effective from 2015. The 2008 regulation also includes more stringent emission standards for remanufactured Tier 0-2 locomotives.

Test Cycles. Locomotive emissions are measured over two steady-state test cycles which represent two different types of service including (1) *line-haul* and (2) *switch* locomotives. The duty cycles include different weighting factors for each of the 8 throttle notch modes, which are used to operate locomotive engines at different power levels, as well as for idle and dynamic brake modes. The switch operation involves much time in idle and low power notches, whereas the line-haul operation is characterized by a much higher percentage of time in the high power notches, especially notch 8.

Locomotive certification and compliance programs include several provisions, including production line testing (PLT) program, in-use compliance emission testing, as well as averaging, banking and trading (ABT) of emissions.

Fuels. To enable catalytic aftertreatment methods at the Tier 4 stage, the EPA regulated (as part of the nonroad Tier 4 rule) the availability of low sulfur diesel fuel for locomotive engines. Sulfur limit of 500 ppm is effective as of June 2007, sulfur limit of 15 ppm from June 2012.

Emission regulations for locomotives and locomotive engines can be found in the US Code of Federal Regulations, 40 CFR Parts 85, 89 and 92.

Tier 0-2 Standards

Three separate sets of emission standards have been adopted, termed Tier 0, Tier 1, and Tier 2. The applicability of the standards depends on the date a locomotive is first manufactured, as follows:

- Tier 0 — The first set of standards applies (effective 2000) to locomotives and locomotive engines originally manufactured from 1973 through 2001, any time they are manufactured or remanufactured.

- Tier 1 — These standards apply to locomotives and locomotive engines originally manufactured from 2002 through 2004. These locomotives and locomotive engines are required to meet the Tier 1 standards at the time of the manufacture and each subsequent remanufacture.

- Tier 2 — This set of standards applies to locomotives and locomotive engines originally manufactured in 2005 and later. Tier 2 locomotives and locomotive engines are required to meet the applicable standards at the time of original manufacture and each subsequent remanufacture.

Exempted from the emission standards are electric locomotives, historic steam-powered locomotives, and locomotives originally manufactured before 1973.

The Tier 0-2 emission standards, as well as typical emission rates from non-regulated locomotives, are listed in Table 1. A dual cycle approach has been adopted in the regulation, i.e., all locomotives are required to comply with both the line-haul and switch duty cycle standards, regardless of intended usage. Locomotive engines must also meet smoke opacity standards, Table 2.

Table 1
Tier 0-2 Locomotive Emission Standards, g/bhp·hr

Duty Cycle	HC*	CO	NO_x	PM
Tier 0 (1973 - 2001)				
Line-haul	1.0	5.0	9.5	0.60
Switch	2.1	8.0	14.0	0.72
Tier 1 (2002 - 2004)				
Line-haul	0.55	2.2	7.4	0.45
Switch	1.2	2.5	11.0	0.54
Tier 2 (2005 and later)				
Line-haul	0.3	1.5	5.5	0.20
Switch	0.6	2.4	8.1	0.24
Non-Regulated Locomotives (1997 estimates)				
Line-haul	0.5	1.5	13.5	0.34
Switch	1.1	2.4	19.8	0.41
* HC standard is in the form of THC for diesel engines				

Table 2 Locomotive Smoke Standards, % opacity (normalized)			
	Steady-state	30-sec peak	3-sec peak
Tier 0	30	40	50
Tier 1	25	40	50
Tier 2 and later	20	40	50

Tier 3-4 Standards

The 2008 regulation strengthens the Tier 0-2 standards for existing locomotives, and introduces new Tier 3 and Tier 4 emission standards:

- Tier 0-2 standards — More stringent emission standards for existing locomotives when they are remanufactured,
- Tier 3 standards — Near-term engine-out emission standards for newly-built and remanufactured locomotives. Tier 3 standards are to be met using engine technology.
- Tier 4 standards — Longer-term standards for newly-built and remanufactured locomotives. Tier 4 standards are expected to require the use of exhaust gas aftertreatment technologies, such as particulate filters for PM control, and urea-SCR for NO_x emission control.

The locomotive regulations apply for locomotives originally built in or after 1973 that operate extensively within the United States. Exceptions include (1) historic steam-powered locomotives, (2) electric locomotives, and (3) some existing locomotives owned by small businesses. Furthermore, engines used in locomotive-type vehicles with less than 750 kW total power (used primarily for railway maintenance), engines used only for hotel power (for passenger railcar equipment), and engines that are used in self-propelled passenger-carrying railcars, are excluded from the regulations. The engines used in these smaller locomotive-type vehicles are generally subject to the non-road engine requirements.

The emission standards are summarized in Table 3 and Table 4. The Tier 0-2 standards apply to existing locomotives of the indicated manufacture years (MY) at the time they are remanufactured, beginning from the effective date. The Tier 3-4 standards apply to locomotives of the indicated manufacture years at the time they are newly built or remanufactured.

Tier 3-4 locomotives must also meet smoke opacity standards as specified in Table 2.

Manufacturers may certify Tier 0-2 locomotives to an alternate CO emission standard of 10.0 g/bhp-hr if they also certify those locomotives to alternate PM standards less than or equal to one-half of the otherwise applicable PM standard.

Locomotives may discharge crankcase emissions to the ambient atmosphere if the emissions are added to the exhaust emissions (either physically or mathematically) during all emission testing.

Useful Life. The emission standards apply to new and/or remanufactured locomotives for their useful life. The useful life, generally specified as MW-hrs and years, ends when either of the values (MW-hrs or years) is exceeded or the locomotive is remanufactured.

The minimum useful life in terms of MW-hrs is equal to the product of the rated horsepower multiplied by 7.50. The minimum useful life in terms of years is 10 years. For locomotives originally manufactured before January 1, 2000 and not equipped with MW-hr meters, the minimum useful life is equal to 750,000 miles or 10 years, whichever is reached first. The minimum emission warranty period is one-third of the useful life (with some exceptions).

Table 3 Line-Haul Locomotive Emission Standards, g/bhp·hr						
Tier	MY	Date	HC	CO	NO_x	PM
Tier 0[a]	1973-1992[c]	2010[d]	1.00	5.0	8.0	0.22
Tier 1[a]	1993[c]-2004	2010[d]	0.55	2.2	7.4	0.22
Tier 2[a]	2005-2011	2010[d]	0.30	1.5	5.5	0.10[e]
Tier 3[b]	2012-2014	2012	0.30	1.5	5.5	0.10
Tier 4	2015 or later	2015	0.14[f]	1.5	1.3[f]	0.03

Table 4 Switch Locomotive Emission Standards, g/bhp·hr						
Tier	MY	Date	HC	CO	NO_x	PM
Tier 0	1973-2001	2010[b]	2.10	8.0	11.8	0.26
Tier 1[a]	2002-2004	2010[b]	1.20	2.5	11.0	0.26
Tier 2[a]	2005-2010	2010[b]	0.60	2.4	8.1	0.13[c]
Tier 3	2011-2014	2011	0.60	2.4	5.0	0.10
Tier 4	2015 or later	2015	0.14[d]	2.4	1.3[d]	0.03

a - Tier 1-2 switch locomotives must also meet line-haul standards of the same tier.
b - As early as 2008 if approved engine upgrade kits become available.
c - 0.24 g/bhp-hr until January 1, 2013 (with some exceptions).
d - Manufacturers may elect to meet a combined NO_x+HC standard of 1.3 g/bhp-hr.

Marine Diesels

Background

Engine Categories. For the purpose of emission regulations, marine engines are divided into three categories based on displacement (swept volume) per cylinder, as shown in Table 1. Each of the categories represents a different engine technology. Categories 1 and 2 are further divided into subcategories, depending on displacement and net power output.

Category 3 marine diesel engines typically range in size from 2,500 to 70,000 kW (3,000 to 100,000 hp). These are very large marine diesel engines used for propulsion power on ocean-going vessels such as container ships, oil tankers, bulk carriers, and cruise ships. Emission control technologies which can be used on these engines are limited. An important limitation is the residual fuel on which they are operated. This fuel is the by-product of distilling crude oil to produce lighter petroleum products. It possesses high viscosity and density, which affects ignition quality, and it typically has high ash, sulfur and nitrogen content in comparison to marine distillate fuels. Furthermore, residual fuel parameters are highly variable because its content is not regulated. The EPA estimated that residual fuel can increase engine NO_x emissions from 20-50% and PM from 750% to 1250% (sulfate particulates) when compared to distillate fuel.

Table 1. Marine Engine Categories

Category	Displacement per Cylinder (D)		Basic Engine Technology
	Tier 1-2	Tier 3-4	
1	D < 5 dm³†	D < 7 dm³	Land-based nonroad diesel
2	5 dm³ ≤ D < 30 dm³	7 dm³ ≤ D < 30 dm³	Locomotive engine
3	D ≥ 30 dm³		Unique marine engine design

† And power ≥ 37 kW

Category 1 and Category 2 marine diesel engines typically range in size from about 500 to 8,000 kW (700 to 11,000 hp). These engines are used to provide propulsion power on many kinds of vessels including tugboats, pushboats, supply vessels, fishing vessels, and other commercial vessels in and around ports. They are also used as stand-alone generators for auxiliary electrical power on many types of vessels.

Regulatory Acts. Emissions from marine diesel engines (compression ignition engines) have been regulated through a number of rules — the first one issued in 1999 — applicable to different engine categories. Certain overlap also exists with the regulations for mobile, land-based nonroad engines, which may be applicable to some types of engines used on marine vessels. The following are the major regulatory acts which establish emission standards for marine engines:

- 1999 Marine Engine Rule — On November 23, 1999, the EPA signed the final rule "Control of Emissions of Air Pollution from New CI Marine Engines at or above 37 kW" *[40 CFR Parts 89, 92][64 FR 64 73300-73373, 29 Dec 1999].* The adopted Tier 2 standards for Category 1 and 2 engines are based on the land-based standard for nonroad engines, while the largest Category 3 engines are expected — but not required by the rule — to comply with IMO MARPOL Annex VI limits.

- 2002 Recreational Engine Rule — Diesel engines used in recreational vessels are covered in the "Emission Standards for New Nonroad Engines — Large Industrial Spark-ignition Engines, Recreational Marine Diesel Engines, and Recreational Vehicles" regulation, signed on September 13, 2002 *[40 CFR Part 89 et al.][67 FR 68241-68447, 8 Nov 2002].*

- 2003 Category 3 Engine Rule — The decision to leave the largest Category 3 engines unregulated triggered a law suit against the EPA by environmental organizations. A court settlement was reached that required the EPA to develop NO_x emission limits for Category 3 engines. The final rule "Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters Per Cylinder" *[40 CFR Part 9 and 94][68 FR 9745-9789, 28 Feb 2003]* — signed by the EPA in January 2003 — establishes Tier 1 emission standards for marine engines virtually equivalent to the IMO MARPOL Annex VI limits.

- 2008 Category 1/2 Engine Rule — A regulation signed on March 14, 2008 introduced Tier 3 and Tier 4 emission standards for marine diesel engines *[73 FR 88 25098-25352, 6 May 2008].* The Tier 4 emission standards are modeled after the 2007/2010 highway engine program and the Tier 4 nonroad rule, with an emphasis on the use of emission aftertreatment technology. To enable catalytic aftertreatment methods, the EPA established a sulfur cap in marine fuels (as part of the nonroad Tier 4 rule). Sulfur limit of 500 ppm becomes effective in June 2007, sulfur limit of 15 ppm in June 2012 (the sulfur limits are not applicable to residual fuels).

- 2009 Category 3 Engine Rule — On December 18, 2009, the EPA signed a new emission rule for Category 3 engines (published April 30, 2010), which introduced Tier 2 and Tier 3 standards in harmonization with the 2008 Amendments to IMO MARPOL Annex VI.

Applicability

1999 Marine Engine Rule. The scope of application of the marine engine rule covers all new marine diesel engines at or above 37 kW (50 hp) (engines below 37 kW must comply with the nonroad standards). Regulated engines include both propulsion and auxiliary marine diesel engines. A propulsion engine is one that moves a vessel through the water or assists in guiding the direction of the vessel (for example, bow thrusters). Auxiliary engines are all other marine engines.

Classification of drilling rigs depends on their propulsion capability. Drilling ships are considered marine vessels, so

their engines are subject to the marine rule. Semi-submersible drilling rigs which are moored to the ocean bottom, but have some propulsion capability, are also considered marine vessels. In contrast, permanently anchored drilling platforms are not considered marine vessels, so none of the engines associated with one of these facilities are marine engine.

Consistently with the land-based nonroad regulation, a portable auxiliary engine that is used onboard a marine vessel is not considered to be a marine engine. Instead, a portable auxiliary engine is considered to be a land-based auxiliary engine and is subject to the land-based nonroad requirements. To distinguish a marine auxiliary engine installed on a marine vessel from a land-based portable auxiliary engine used on a marine vessel, EPA specified in that rulemaking that an auxiliary engine is installed on a marine vessel if its fuel, cooling, or exhaust system are an integral part of the vessel or require special mounting hardware. All other auxiliary engines are considered to be portable and therefore land-based.

The following engine categories are exempted from the 1999 marine regulation:

- Engines used in recreational vessels (standards for recreational diesel engines were established by the 2002 rule);
- Emission certified new land-based engines modified for marine applications (provided certain conditions are met);
- Competition (racing) engines;
- Engines used in military vessels (National Security Exemption);
- Other exemptions (testing, display, export, ...) may also apply to marine engines.

The 1999 rule also included so called Foreign-Trade Exemption which was available (for engines Category 1 and 2 used on ocean vessels with Category 3 propulsion) for US vessels that spend less than 25% of total operating time within 320 kilometers of US territory. The Foreign-Trade Exemption was eliminated for all engine categories by the 2003 (Category 3) regulation.

Under the 1999 rule, the same emission standards apply to engines fueled by diesel fuel and by other fuels.

2002 Recreational Vessel Rule. This rule applies to new recreational marine diesel engines over 37 kW (50 hp) that are used in yachts, cruisers, and other types of pleasure craft. The 2002 rule does not apply to outboard and personal watercraft spark ignited engines, which are regulated separately.

The same emission standards apply to recreational engines fueled by diesel fuel and by alternative fuels.

Category 3 Engines, 2003 & 2009 Rules. These standards apply to new marine engines and to new vessels that include marine engines. The rules apply only to vessels flagged or registered in the USA. However, equivalent emission standards are applicable to foreign ships in US waters under the IMO Annex VI regulation.

Category 1/2 Engines, 2008 Rule. The regulations introduce two tiers of standards — Tier 3 and Tier 4 — which apply to both newly manufactured and remanufactured marine diesel engines, as follows:

i. *Newly-built engines:* Tier 3 standards apply to engines used in commercial, recreational, and auxiliary power applications (including those below 37 kW that were previously covered by nonroad engine standards). Tier 4 standards, based on aftertreatment, apply to engines above 600 kW (800 hp) on commercial vessels.

ii. *Remanufactured engines:* The standards apply to commercial marine diesel engines above 600 kW when these engines are remanufactured.

The 2008 rule includes exemptions for the following engine categories:

- Test engines, manufacturer-owned engines, display engines;
- Marine diesel engines that are produced by marinizing a certified highway, nonroad, or locomotive engine ("dresser exemption");
- Competition engines;
- Export engines;
- Certain military engines;
- Engines installed on a vessel manufactured by a person for his/her own use (intended to allow hobbyists and fishermen to install a used/rebuilt engine or a reconditioned vintage engine — not to order a new uncontrolled engine from an engine manufacturer).

Not all exemptions are automatic. Engine or vessel manufacturers, or vessel owners, may need to apply for a specific exemption to the EPA.

Emission Standards — Category 3

Tier 1 Standards. In the 2003 rule, EPA adopted Tier 1 NO_x emission standards for Category 3 engines, which are equivalent to the international IMO MARPOL Annex VI limits. These limits range from 17 to 9.8 g/kWh depending on the engine speed, with higher limits for slower engines.

The EPA Tier 1 limits are in effect for new engines built in 2004 and later. These limits are to be achieved by engine-based controls, without the need for exhaust gas aftertreatment. Emissions other than NO_x are not regulated.

Tier 2-3 Standards. In the 2009 rule, EPA has adopted Tier 2 and Tier 3 emission standards for newly built Category 3 engines.

- Tier 2 standards apply beginning in 2011. They require the use of engine-based controls, such as engine timing, engine cooling, and advanced electronic controls. The Tier 2 standards result in a 15 to 25% NO_x reduction below the Tier 1 levels.
- Tier 3 standards apply beginning in 2016. They can be met with the use of high efficiency emission control technology such as selective catalytic reduction (SCR) to achieve NO_x reductions 80% below the Tier 1 levels.

Table 2. Tier 2* Marine Emission Standards

Category	Displacement (D)	CO	NO_x+THC	PM	Date
	dm^3 per cylinder	g/kWh	g/kWh	g/kWh	
1	Power ≥ 37 kW D < 0.9	5.0	7.5	0.40	2005
	0.9 ≤ D < 1.2	5.0	7.2	0.30	2004
	1.2 ≤ D < 2.5	5.0	7.2	0.20	2004
	2.5 ≤ D < 5.0	5.0	7.2	0.20	2007[a]
2	5.0 ≤ D < 15	5.0	7.8	0.27	2007[a]
	15 ≤ D < 20 Power < 3300 kW	5.0	8.7	0.50	2007[a]
	15 ≤ D < 20 Power ≥ 3300 kW	5.0	9.8	0.50	2007[a]
	20 ≤ D < 25	5.0	9.8	0.50	2007[a]
	25 ≤ D < 30	5.0	11.0	0.50	2007[a]

* - Tier 1 standards are equivalent to the MARPOL Annex VI Tier I NO_x limits
a - Tier 1 certification requirement starts in 2004

The EPA Tier 2-3 NO_x limits are equivalent to the respective IMO Tier II-III standards. Depending on the engine speed, Tier 2 limits range from 14.4 to 7.7 g/kWh, while Tier 3 limits range from 3.4 to 1.96 g/kWh. In addition to the NO_x limits, EPA adopted a HC emission standard of 2.0 g/kWh and a CO standard of 5.0 g/kWh from new Category 3 engines. No emission standard was adopted for PM, but manufacturers are required to measure and report PM emissions.

IMO Emission Control Areas (ECA). The IMO has designated waters along the US and Canadian shorelines as the North American ECA for the emissions of NO_x and SO_x (enforceable from August 2012) and waters surrounding Puerto Rico and the US Virgin Islands as the US Caribbean ECA for NO_x & SO_x (enforceable from 2014).

The ECAs ensure that foreign flagged vessels comply with IMO Tier III NO_x limits while in US waters (the IMO Tier III standards are only applicable within ECAs). The ECA also triggers low sulfur fuel requirements — by IMO and US EPA — for vessels in US waters.

Emission Standards — Category 1 And 2

Tier 1-2 Standards. Emission standards for engines Category 1 and 2 are based on the land-based standard for nonroad and locomotive engines. The emission standards, referred to as Tier 2 Standards by the EPA, and their implementation dates are listed in the following table. The Tier 1 NO_x standard, equivalent to MARPOL Annex VI, was voluntary under the 1999 rule, but was made mandatory by the 2003 (Category 3) rule for Category 2 and Category 1 engines of above 2.5 liter displacement per cylinder, effective 2004.

The regulated emissions include NO_x+THC, PM, and CO. There are no smoke requirements for marine diesel engines. The regulators believed that the new PM standards will have a sufficient effect on limiting smoke emissions.

In the earlier proposal, the EPA also listed a more stringent Tier 3 standard to be introduced between 2008 and 2010. The Tier 3 standard was not adopted in the final 1999 rule.

Blue Sky Series Program. The 1999 regulation sets a voluntary "Blue Sky Series" program which permits manufacturers to certify their engines to more stringent emission standards. The qualifying emission limits are listed in Table 3. The Blue Sky program begins upon the publication of the rule and extends through the year 2010.

Table 3. "Blue Sky Series" Voluntary Emission Standards

Displacement (D)	NO_x+THC	PM
dm^3 per cylinder	g/kWh	g/kWh
Power ≥ 37 kW & D < 0.9	4.0	0.24
0.9 ≤ D < 1.2	4.0	0.18
1.2 ≤ D < 2.5	4.0	0.12
2.5 ≤ D < 5.0	5.0	0.12
5.0 ≤ D < 15	5.0	0.16
15 ≤ D < 20 & Power < 3300 kW	5.2	0.30
15 ≤ D < 20 & Power ≥ 3300 kW	5.9	0.30
20 ≤ D < 25	5.9	0.30
25 ≤ D < 30	6.6	0.30

Recreational Vessels (2002 Rule). Recreational vessels standards are phased-in beginning in 2006, depending on the size of the engine as listed in Table 4. These standards are similar to the Tier 2 standards for Category 1 commercial vessels.

Table 4. Recreational Marine Diesel Engines Standards

Displacement (D)	CO	NO_x+HC	PM	Date
dm^3 per cylinder	g/kWh	g/kWh	g/kWh	
0.5 ≤ D < 0.9	5.0	7.5	0.40	2007
0.9 ≤ D < 1.2	5.0	7.2	0.30	2006
1.2 ≤ D < 2.5	5.0	7.2	0.20	2006
D ≥ 2.5	5.0	7.2	0.20	2009

Recreational engines are also subject to NTE limits. There are no smoke requirements for recreational marine diesel engines. Similarly to commercial vessels, a voluntary "Blue Sky Series" limits exist for recreational vessels, which are based on a 45% emission reduction beyond the mandatory standards.

Tier 3-4 Standards. The standards and implementation schedules are shown in Table 5 through Table 8. The engine-based Tier 3 standards are phasing in over 2009-2014. The aftertreatment-based Tier 4 standards for commercial marine engines at or above 600 kW are phasing in over 2014-2017. For engines of power levels not included in the Tier 3 and Tier 4 tables, the previous tier of standards — Tier 2 or Tier 3, respectively — continues to apply.

A differentiation is made between *high power density engines* typically used in planing vessels and *standard power density engines,* with a cut point between them at 35 kW/dm^3 (47 hp/dm^3).

Table 5. Tier 3 Standards for Marine Diesel Category 1 Commercial Standard Power Density (≤ 35 kW/dm^3) Engines

Power (P)	Displacement (D)	NO_x+HC†	PM	Date
kW	dm^3 per cylinder	g/kWh	g/kWh	
P < 19	D < 0.9	7.5	0.40	2009
19 ≤ P < 75	D < 0.9[a]	7.5	0.30	2009
		4.7[b]	0.30[b]	2014
75 ≤ P < 3700	D < 0.9	5.4	0.14	2012
	0.9 ≤ D < 1.2	5.4	0.12	2013
	1.2 ≤ D < 2.5	5.6	0.11[c]	2014
	2.5 ≤ D < 3.5	5.6	0.11[c]	2013
	3.5 ≤ D < 7	5.8	0.11[c]	2012

† Tier 3 NO_x+HC standards do not apply to 2000-3700 kW engines.
a - < 75 kW engines ≥ 0.9 dm^3/cylinder are subject to the corresponding 75-3700 kW standards.
b - Option: 0.20 g/kWh PM & 5.8 g/kWh NO_x+HC in 2014.
c - This standard level drops to 0.10 g/kWh in 2018 for < 600 kW engines.

Table 6. Tier 3 Standards for Marine Diesel Category 1 Commercial High Power Density (> 35 kW/dm^3) Engines And All Diesel Recreational Engines

Power (P)	Displacement (D)	NO_x+HC	PM	Date
kW	dm^3 per cylinder	g/kWh	g/kWh	
P < 19	D < 0.9	7.5	0.40	2009
19 ≤ P < 75	D < 0.9[a]	7.5	0.30	2009
		4.7[b]	0.30[b]	2014
75 ≤ P < 3700	D < 0.9	5.8	0.15	2012
	0.9 ≤ D < 1.2	5.8	0.14	2013
	1.2 ≤ D < 2.5	5.8	0.12	2014
	2.5 ≤ D < 3.5	5.8	0.12	2013
	3.5 ≤ D < 7	5.8	0.11	2012

a - < 75 kW engines ≥ 0.9 dm^3/cylinder are subject to the corresponding 75-3700 kW standards.
b - Option: 0.20 g/kWh PM & 5.8 g/kWh NO_x+HC in 2014.

Table 7. Tier 3 Standards for Marine Diesel Category 2 Engines‡

Power (P)	Displacement (D)	NO_x+HC†	PM	Date
kW	dm^3 per cylinder	g/kWh	g/kWh	
P < 3700	7 ≤ D < 15	6.2	0.14	2013
	15 ≤ D < 20	7.0	0.27[a]	2014
	20 ≤ D < 25	9.8	0.27	2014
	25 ≤ D < 30	11.0	0.27	2014

‡ Option: Tier 3 PM/NO_x+HC at 0.14/7.8 g/kWh in 2012, and Tier 4 in 2015.
† Tier 3 NO_x+HC standards do not apply to 2000-3700 kW engines.
a - 0.34 g/kWh for engines below 3300 kW.

In addition to the above NO_x+HC and PM standards, the following CO emission standards apply for all Category 1/2 engines starting with the applicable Tier 3 model year:

i. 8.0 g/kWh for engines < 8 kW,

ii. 6.6 g/kWh for engines ≥ 8 kW and < 19 kW,

iii. 5.5 g/kWh for engines ≥ 19 kW and < 37 kW,

iv. 5.0 g/kWh for engines ≥ 37 kW.

Table 8. Tier 4 Standards for Marine Diesel Category 1/2 Engines				
Power (P)	**NO_x**	**HC**	**PM**	**Date**
kW	g/kWh	g/kWh	g/kWh	
P ≥ 3700	1.8	0.19	0.12[a]	2014[c]
	1.8	0.19	0.06	2016[b,c]
2000 ≤ P < 3700	1.8	0.19	0.04	2014[c,d]
1400 ≤ P < 2000	1.8	0.19	0.04	2016[c]
600 ≤ P < 1400	1.8	0.19	0.04	2017[d]

a - 0.25 g/kWh for engines with 15-30 dm^3/cylinder displacement.
b - Optional compliance start dates can be used within these model years.
c - Option for Cat. 2: Tier 3 PM/NO_x+HC at 0.14/7.8 g/kWh in 2012, and Tier 4 in 2015.
d - The Tier 3 PM standards continue to apply for these engines in model years 2014 and 2015 only.

Emission Testing

Category 1/2 Engines. Emissions from Category 1 engines are tested using the nonroad (Tier 1-3) test procedures (40 CFR 89), while Category 2 engines are tested using the locomotive test procedures (40 CFR 92), with certain exceptions including different test cycles, certification fuels and NTE testing. Category 1/2 engines are tested on various ISO 8178 test cycles as summarized in Table 9.

Table 9. Test Cycles for Certifying Category 1/2 Marine Diesel Engines	
Application	**Test Cycle**
General Marine Duty Cycle	ISO 8178 E3
Constant-Speed Propulsion Engines	ISO 8178 E2
Variable Speed Propulsion Engines Used on Non-Propeller Law Vessels and Variable Speed Auxiliary Engines	ISO 8178 C1
Constant-Speed Auxiliary Engines	ISO 8178 D2
Recreational Marine	ISO 8178 E5

In addition to the test cycle measurement, which is an average from several test modes, the regulations set "not-to-exceed" (NTE) emission limits, which provide assurance that emissions at any engine operating conditions within an NTE zone are reasonably close to the average level of control. NTE zones are defined as areas on the engine speed-power map. The emission caps within the NTE zones represent a multiplier (Tier 1/2: between 1.2 and 1.5; Tier 3/4: 1.2-1.9) times the weighted test result used for certification for all of the regulated pollutants (NO_x+THC, CO, and PM).

The test fuel for marine diesel engine testing has a sulfur specification range of 0.03 to 0.80 %wt, which covers the range of sulfur levels observed for most in-use fuels.

Category 3 Engines. Category 3 engines are tested using methods similar to those stipulated by IMO MARPOL Annex VI (E2 and E3 cycles of the ISO 8178 test). The major differences between the EPA and MARPOL compliance requirements are: (1) EPA liability for in-use compliance rests with the engine manufacturer (it is the vessel operator in MARPOL), (2) EPA requires a durability demonstration (under MARPOL, compliance must be demonstrated only when the engine is installed in the vessel), (3) there are differences in certain test conditions and parameters in EPA and MARPOL testing (air and water temperatures, engine setting, etc.).

Category 3 engines have no NTE emission limits or test requirements.

Category 3 engines can be tested using distillate fuels, even though vessels with Category 3 marine engines use primarily residual fuels (this allowance is consistent with MARPOL Annex VI).

Other Provisions

Useful life and *warranty* periods for marine engines are listed in Table 10. The periods are specified in operating hours and in years, whichever occurs first. The relatively short useful life period for Category 3 engines is based on the time that engines operate before being rebuilt for the first time.

Table 10. Useful Life and Emission Warranty Periods				
Category	**Useful Life**		**Warranty Period**	
	hours	years	hours	years
Category 3	10,000	3	10,000	3
Category 2	20,000	10	10,000	5
Category 1	10,000	10	5,000	5
Recreational	1,000	10	500	3

The periods in the table are the minimum periods specified by the regulations. In certain cases, longer useful life/warranty periods may be required (e.g., in most cases the emission warranty must not be shorter than the warranty for the engine or its components).

The regulations contain several other provisions, such as emission Averaging, Banking, and Trading (ABT) program, deterioration factor requirements, production line testing, in-use testing, and requirements for rebuilding of emission certified engines.

Introduction

On-board diagnostic (OBD) systems provide self-diagnostic functionality incorporated into the engine control system, in order to alert the vehicle driver/operator about potential problems that can affect the emission performance of the vehicle. OBD requirements were first introduced for light-duty vehicles in California in 1991. Today, OBD requirements apply to light-duty vehicles and heavy-duty engines, both in California and under the federal EPA requirements.

The most detailed requirements for OBD systems are provided by the California regulations. Because systems developed for use in California can generally be used for compliance with EPA requirements with only minor differences, it is expected that OBD systems for vehicles and engines sold outside of California will be similar.

California light-duty and heavy-duty regulations define a number of general requirements for the malfunction indicator light (MIL), trouble codes, monitoring, thresholds and standardized communications common to all OBD systems. These requirements — outlined in the following sections — also apply to systems intended to comply with US federal requirements.

MIL & Fault Code Requirements

The Malfunction Indicator Light (MIL) is located on the instrument panel. Except for a functionality check where it illuminates for 15-20 seconds when in the key-on position before engine cranking, it is normally illuminated only when the OBD system has detected and confirmed a malfunction that could increase emissions.

A number of things must happen before the MIL illuminates. When the OBD determines that a malfunction has occurred, it generates and stores a "pending fault code" and a "freeze frame" of engine data. At this point, the MIL does not illuminate. If the malfunction is detected again before the next driving cycle in which the suspected system or component is monitored, the MIL illuminates continuously and a "MIL-on" or "confirmed" fault code is generated and stored as well as a "freeze frame" of engine data. If the malfunction is not detected by the end of the driving cycle, the "pending fault code" is erased.

Except for misfires and fuel system faults, if the malfunction is not detected in the next 3 driving cycles, the MIL can be extinguished but the trouble code is still stored for at least 40 engine warm-up cycles. The MIL can also be extinguished and fault codes erased with a scan tool that technicians use to diagnose malfunctions. Alternate MIL illumination strategies are also possible but subject to approval.

Monitoring

The systems and parameters that require monitoring are outlined in Table 1. While some components can be monitored continuously, this is not always possible. Therefore, manufacturers must define conditions under which important emission control components and subsystems can be monitored for proper function. The monitoring conditions should meet the following requirements:

- ensure robust detection of malfunctions by avoiding false passes and false indications of malfunctions,
- ensure monitoring will occur under conditions that may reasonably be expected to be encountered in normal vehicle operation and use,
- ensure monitoring will occur during the FTP cycle.

In order to quantify the frequency of monitoring, an in-use monitor performance ratio is defined as:

In-use monitoring performance ratio = Number of monitoring events/Number of driving events.

Each component and subsystem requiring monitoring requires its own ratio. For example, for 2013 and later heavy-duty engines, the minimum acceptable value of this ratio is 0.100 (i.e. monitoring should occur at least during 1 vehicle trip in 10).

Table 1
Monitoring Requirements of California OBD Systems

System/Component	Parameter Requiring Monitoring
Fuel system	Fuel system pressure control
	Injection quantity
	Injection timing
	Feedback control
Misfire	Detect continuous misfire
	Determine % of misfiring cycles per 1000 engine cycles (2013 and later engines)
EGR	Low flow
	High flow
	Slow response
	EGR cooler operation
	EGR catalyst performance
	Feedback control

Table 1 Monitoring Requirements of California OBD Systems	
System/Component	**Parameter Requiring Monitoring**
Boost pressure	Underboost
	Overboost
	Slow response
	Charge air under cooling
	Feedback control
NMHC catalyst	Conversion efficiency
	Provide DPF heating
	Provide SCR feedgas (e.g., NO_2)
	Provide post DPF NMHC clean-up
	Provide ammonia clean-up
	Catalyst aging
SCR NO_x catalyst	Conversion efficiency
	SCR reductant: • delivery performance, • tank level, • quality, and • injection feedback control
	Catalyst aging
NO_x adsorber	NO_x adsorber capability
	Desorption function fuel delivery
	Feedback control
DPF	Filtering performance
	Frequent regeneration
	NMHC conversion
	Incomplete regeneration
	Missing substrate
	Active regeneration fuel delivery
	Feedback control
Exhaust gas sensors	For air-fuel ratio and NO_x sensors: • performance, • circuit faults, • feedback, and • monitoring capability
	Other exhaust gas sensors
	Sensor heater function
	Sensor heater circuit faults
VVT	Target error
	Slow response
Cooling system	Thermostat
	ECT sensor circuit faults
	ECT sensor circuit out-of-range
	ECT sensor circuit rationality faults
CCV	System integrity
Comprehensive component monitoring	
Cold start emission reduction strategy	
Other emission control system monitoring	

Comprehensive Component Monitoring requires the monitoring of any electronic engine component/system not specifically covered by the regulation that provides input to or receives commands from on-board computers and that can affect emissions during any reasonable in-use driving condition or is used as part of the diagnostic strategy for any other monitored system or component.

Monitoring is also required for all other emission control systems that are not specifically identified. Examples include: hydrocarbon traps, HCCI control systems or swirl control valves.

Malfunction Criteria

Malfunction criteria for the various malfunctions listed in Table 1 vary depending on the system or component and individual parameter being monitored. In some cases, such as feedback control systems, sensor rationality checks and checks for circuit faults, a go/no-go criteria is used. In other cases such as the fuel system, EGR, turbocharger physical parameters and aftertreatment system performance, the OBD system must be able to determine when deterioration or other changes cause emissions to exceed a specified threshold.

In order to determine malfunction criteria for many of these faults, manufacturers must correlate component and system performance with exhaust emissions to determine when deterioration will cause emissions to exceed a certain threshold. This may require extensive testing and calibration for each engine model.

In determining the malfunction criteria for diesel engine monitors that are required to indicate a malfunction before emissions exceed an emission threshold (e.g., 2.0 times any of the applicable standards), the emission test cycle and standard that would result in higher emissions with the same level malfunction is to be used. Some adjustment is possible for those components experiencing infrequent regeneration.

Manufacturers have the option of simplifying monitoring requirements if failure or deterioration of a parameter will not cause emissions to exceed the threshold limits. For parameters that are controlled, such as temperature, pressure and flow, a malfunction in such a case would only need to be indicated when the commanded setting cannot be achieved. For aftertreatment devices, a malfunction would be indicated when the aftertreatment device has no conversion/filtering capability.

To account for the fact that current technology may not be adequate to detect all malfunctions at the required threshold, some flexibility has been built into the regulations. A manufacturer may request a higher emission threshold for any monitor if the most reliable monitoring method developed requires a higher threshold. Additionally, the PM filter malfunction criteria may be revised to exclude detection of specific failure modes (e.g., partially melted substrates or small cracks) if the most reliable monitoring method developed is unable to detect such failures.

A number of other exceptions are available including the possibility to disable OBD monitoring at ambient engine start temperatures below 20°F or at elevations above 8000 feet above sea level.

Standardization Requirements

OBD systems have a standardization requirement that makes diagnostics possible with a universal scan tool that is available to anyone — not just manufacturer's repair facilities. The standardization requirements include:

- A standard data link connector.
- A standard protocol for communications with a scan tool.
- In-use performance ratio tracking and engine run time tracking requirements.
- Engine manufacturers must provide the aftermarket service and repair industry emission-related service information.
- Standardized functions to allow information to be accessed by a universal scan tool. These functions include:
    - Readiness status: The OBD system indicates "complete" or "not complete" for each of the monitored components and systems.
    - Data stream: A number of specific signals are made available through the standardized data link connector. Some of these include: torque and speed related data, temperatures, pressures, fuel system control parameters, fault codes and associated details, air flow, EGR system data, turbocharger data and aftertreatment data.
    - Freeze frame: The values of many of the important parameters available in the Data Stream are stored when a fault is detected.
    - Fault codes.
    - Test results: Results of the most recent monitoring of the components and systems and the test limits established for monitoring the respective components and systems are stored and made available through the data link.
    - Software calibration identification: Software Calibration Verification Number.
    - Vehicle Identification Number (VIN).
    - Erasing emission-related diagnostic information: The emission-related diagnostic information can be erased if commanded by a scan tool (generic or enhanced) or if the power to the on-board computer is disconnected.

Emissions Standards: Canada
On-Road Engines

Background

Authority to regulate emissions from internal combustion engines in Canada currently rests with *Environment Canada* and *Transport Canada*. The *Canadian Environmental Protection Act 1999* (CEPA 1999) gave legislative authority to Environment Canada to regulate emissions from engines other than those used in aircraft, railway locomotives and commercial marine vessels. Authority to regulate emissions from aircraft, railway locomotives and commercial marine vessels rests with Transport Canada.

Increasingly, the general approach to setting vehicle emissions standards in Canada is to harmonize them with US EPA federal standards as much as possible. In 1988, on-road vehicle emission standards were first aligned with the US federal standards. In February 2001, the Minister of the Environment in the *Federal Agenda on Cleaner Vehicles, Engines and Fuels* set out a number of policy measures that would continue the harmonization of on-road emissions standards as well as to expand this harmonization by developing emission standards for off-road engines and standards for fuels that are aligned with those of the federal US EPA requirements.

On-Road Engines and Vehicles

Canadian federal regulations establishing exhaust emission limits for on-road vehicles were first promulgated in 1971 under the *Motor Vehicle Safety Act* which is administered by Transport Canada. On March 13, 2000, legislative authority for controlling on-road vehicle emissions was transferred to Environment Canada under the Canadian Environmental Protection Act 1999 (CEPA 1999). Under CEPA 1999, the *On-Road Vehicle and Engine Emission Regulations* where promulgated on January 1, 2003, and came into effect on January 1, 2004. These regulations replaced the previous regulations adopted under the Motor Vehicle Safety Act. The new regulations adopted under CEPA 1999 continued the past approach of aligning with the federal emission standards of the US EPA.

MOU. In the interim period between the phase-out of the emission regulations under the Motor Vehicle Safety Act and the effective date of the On-Road Vehicle and Engine Emission Regulations, Environment Canada signed a *Memorandum of Understanding* (MOU) with the Canadian Vehicle Manufacturers Association, the Association of International Automobile Manufacturers of Canada, and the member companies of those associations in June 2001. The MOU formalized an industry commitment to market the same low emission light-duty vehicles and light-duty trucks in Canada as in the US for model years 2001-2003.

On-Road Emission Regulations. The Regulations align vehicle and engine certification requirements with those of the US federal EPA requirements beginning January 1, 2004 and including the US Tier 2 program for new light-duty vehicles, light-duty trucks and medium-duty passenger vehicles, and Phase 1 and Phase 2 programs for new heavy-duty vehicles and engines.

The Regulations set out technical standards for vehicles and engines for exhaust, evaporative and crankcase emissions, on-board diagnostic systems and other specifications related to emission control systems. The intention of the Regulations is to ensure that vehicles and engines meeting more stringent exhaust emission standards will begin entering the Canadian market in the 2004 model year and will be phased-in over the 2004 to 2010 model year period. The phase-in schedules vary by standard and by vehicle class and can be summarized as follows:

- Tier 2 standards for light-duty vehicles and light light-duty trucks (2004-2007).
- Tier 2 standards for heavy light-duty trucks and medium-duty passenger vehicles (2004-2009).
- Phase 1 (2005) and Phase 2 (2008-2009) standards for complete heavy-duty vehicles.
- Phase 1 (2004-2006) and Phase 2 (2007-2010) standards for heavy-duty engines.

During any phase-in period, every model of vehicle or engine that is certified by the US EPA, and that is sold concurrently in Canada and the United States, is required to meet the same emission standards in Canada as in the United States. Canadian vehicles will therefore have progressively improved emission performance without specifying interim phase-in percentages in the Regulations. The final phased-in standards apply to all vehicles and engines sold in Canada, in the model year that they apply, to 100% of a class of vehicles or engines in the United States.

Vehicle Weight Classes. The regulations define the weight classes for vehicles and engines as outlined below:

Table 1
Vehicle Categories

Class	GVWR, kg (lb)
Motorcycle	≤793 (1,749)
Light-Duty Vehicle	≤3,856 (8,500)
Light-Duty Truck	≤3,856 (8,500)
- light light-duty truck	≤2,722 (6,000)
- heavy light-duty truck	>2,722 to 3,856 (6,000 to 8,500)
Medium-Duty Passenger Vehicle	3,856 to <4,536 (8,500 to 10,000)
Complete Heavy-Duty Vehicle (Otto cycle only)	3,856 to 6,350 (8,500 to 14,000)
Heavy-Duty Vehicle/Heavy-Duty Engine	>3,856 (8,500)
- light heavy-duty engine	<8,847 (19,500)
- medium heavy-duty engine	8,847 to 14,971 (19,500 to 33,000)
- heavy heavy-duty engine	>14,971 (33,000)

Light-Duty Vehicles

The exhaust emission standards for Light-Duty Vehicles, Light-Duty Trucks and Medium-Duty Passenger Vehicles align with the US Tier 2 emission standards. Manufacturers certify every vehicle to one of eleven "bins", each of which contains standards for NO_x, non-methane organic gases (NMOG), CO, formaldehyde and PM (see table in US section). The manufacturers' choices of bin within which to certify each vehicle is limited by the obligation to comply with fleet average NO_x emissions standards.

Based on vehicle sales from each "bin", a company calculates a sales-weighted "fleet average NO_x value" for each model year. The emission bins, fleet average NO_x emission standards, timing of phase-ins and methods of calculating fleet average NO_x values are consistent with the US Tier 2 emission program. As in the US program, the Canadian standards have separate fleet average requirements for LDV/LLDTs and HLDT/MDPVs until the end of the 2008 model year. However, there are no separate distinctions between Tier 2 vehicles and interim non-Tier 2 vehicles as in the US program. All Canadian Tier 2 LDV/LLDTs must meet one fleet average requirement and all HLDT/MDPVs another, as outlined in Table 2.

Table 2
Canadian Fleet average NO_x requirements, g/mile

Model Year	LDV/LLDTs	HLDT/MDPV
2004	0.25	0.53
2005	0.19	0.43
2006	0.13	0.33
2007	0.07	0.20
2008	0.07	0.14
2009 & later	0.07	

While this results in an upper fleet average LDV/LLDT NO_x limit that is equal to that obtained for the US Tier 2 program, there is a small difference for 2004-2006 HLDT/MDPVs fleet average NO_x limit for Canada. For the US 2004-2006 model year HLDT/MDPVs, a significant proportion of sales do not have to meet Tier 2 or interim non-Tier 2 fleet average NO_x requirements. The only stipulation is that they meet bin 10 requirements if they are HLDTs or bin 11 requirements if they are MDPVs. The Canadian regulations require that all HLDT/MDPVs meet a fleet average NO_x requirement during this period.

As in the US Tier 2 program, by 2009 when the standards are fully phased in, a company's combined fleet of light-duty vehicles, light-duty trucks and medium-duty passenger vehicles will be subject to a single fleet average NO_x emission standard of 0.07 g/mile, corresponding to the NO_x standard in bin 5. A company can, in any model year, generate NO_x emission credits by achieving a fleet average NO_x value that is lower than the standard. These credits can be used in a subsequent model year to offset a NO_x emissions deficit (the fleet average NO_x value exceeds the standard). A deficit must be offset no later than the third model year following the year in which it is incurred. NO_x emission credits may also be transferred to another company.

In order to allow some flexibility in the regulations to account for market differences between Canada and the US, the Canadian regulations allow a company to exclude from the fleet average compliance requirement US certified vehicles that are sold concurrently in Canada and the USA. For vehicle models certified to emission bins having a NO_x standard higher than the fleet average, this is not allowed if the total number of vehicles of the particular model sold in Canada exceeds the number sold in the USA. If a company chooses this option, they must include all eligible vehicles in that group, they cannot generate emission credits or transfer credits to another company in that model year and they forfeit any emission credits obtained in previous model years. In all cases, fleet average emissions must be reported at the end of the year.

Heavy-Duty Engines

Diesel Engines. Phase 1 standards for heavy-duty diesel truck and bus engines apply starting with the 2004 model year. As with the US EPA, there are two options for NO_x+NMHC limits and tighter standards for urban busses (see US table). Phase 2 standards apply starting with the 2007 model year.

In the USA, the Phase 2 NMHC, CO and PM standards apply in 2007 and the NO_x standard is phased in from 2007-2010. In the case of a standard that is set out in the US Code of Federal Regulations (CFR) to be phased in over a period of time, the standard comes into effect in Canada in the model year for which the CFR specifies that the standard applies to 100% of that class, and continues to apply until another standard comes into effect that applies to 100% of that class. This creates a difference in Canadian and US standards during this phase in period. However, because every engine that is covered by an EPA certificate and that is sold concurrently in Canada and the US must conform to the EPA certification and in-use standards, the differences in emission profiles of engines sold during this period are expected to be small.

There are no emission averaging, banking and trading options for heavy-duty engines in Canada.

Otto Engines. The standards for heavy-duty Otto cycle engines are outlined in Table 3. Phase 2 standards are the same as those for heavy-duty diesel engines and apply in 2008. As with the heavy-duty diesel engine standards, the NO_x standards

Table 3
Heavy-Duty Otto Engine Emission Standards, g/bhp-hr

	GVWR kg (lb)	NO_x	NMHC	NO_x + NMHC	CO	PM
Pre-2005	≤ 6,350 (14,000)	4.0	1.1	-	14.4	-
	> 6,350 (14,000)	4.0	1.9	-	37.1	-
Phase 1 (2005)	≤ 6,350 (14,000)	-	-	1.0	14.4	-
	> 6,350 (14,000)	-	-	1.0	37.1	-
Phase 2 (2008 - 2010)	≥ 3,856 (8,500)	0.2	0.14	-	14.4	0.01

in the USA are phased in and apply to 100% of engines in 2010. Similar comments apply here as those noted above for heavy-duty diesel engines during this phase-in period.

Heavy-Duty Vehicles

Complete Heavy-Duty Vehicles. A complete heavy-duty vehicle is one with a gross vehicle weight rating of 6350 kg (14,000 pounds) or less and that is powered by an Otto-cycle engine and with the load carrying device or container attached after it leaves the control of the manufacturer. As with the US EPA requirements, Phase 1 standards apply starting in the 2005 model year. Because the Phase 2 standards are phased in during 2008 in the USA and apply to 100% of US vehicles only in 2009, similar comments to those made previously for heavy-duty diesel engines apply. The standards for these vehicles are outlined in Table 4:

Table 4
Complete Heavy-Duty Vehicle Exhaust Emission Standards, g/mi

	GVWR kg (lb)	NO_x	NMHC	HCHO	CO	PM
Phase 1 (2005)	3,856 - 4,536 (8,500 - 10,000)	0.9	0.28	-	7.3	-
	4,536 - 6,350 (10,000 - 14,000)	1	0.33	-	8.1	-
Phase 2 (2008 - 2009)	3,856 - 4,536 (8,500 - 10,000)	0.2	0.195	0.032	7.3	0.02
	4,536 - 6,350 (10,000 - 14,000)	0.4	0.23	0.04	8.1	0.02

Heavy-Duty Vehicles. On-road heavy-duty vehicles other than complete heavy-duty vehicles must meet the heavy-duty engine requirements for the particular engine installed in that vehicle. Alternatively, heavy-duty diesel vehicles of 6,350 kg (14,000 lb) GVWR or less can conform to the standards for complete heavy-duty vehicles.

There are no emission averaging, banking and trading options for heavy-duty vehicles or complete heavy-duty vehicles in Canada.

Emissions Standards: Canada
Off-Road Engines And Vehicles

Emission regulations have been adopted for the following categories of off-road engines:

- Off-Road Compression-Ignition Engines, such as those used in construction and agricultural machinery,
- Off-Road Small Spark-Ignition Engines, and
- Marine Engines

The authority for regulating railway locomotive emissions lies with Transport Canada under the Railway Safety Act. Environment Canada monitored locomotive emissions through information provided under a MOU signed by Environment Canada, the Canadian Council of Ministers of the Environment and the Railway Association of Canada in 1995. The MOU set a cap on annual NO_x emissions from railway locomotives operating in Canada of 115,000 tonnes per annum. Since this agreement expired in 2005, locomotive emissions remain unregulated.

Off-Road Compression-Ignition Engines

Prior to the *Canadian Environmental Protection Act 1999* (CEPA 1999), there was no federal authority for regulating emissions from off-road engines such as those typically found in construction, mining, farming and forestry machines. Under the December 2000 Ozone Annex to the 1991 Canada-United States Air Quality Agreement, Canada committed to establishing emission regulations under CEPA 1999 for new off-road engines that aligned with the US federal EPA requirements. In the period before the regulations were promulgated, Environment Canada signed MOUs with 13 engine manufacturers in 2000. Under the terms of these MOUs, manufacturers agreed to supply off-road diesel engines designed to meet US EPA Tier 1 standards.

The Off-Road Compression-Ignition Engine Emission Regulations were promulgated on February 23, 2005. These regulations introduced emission standards for model year 2006 and later diesel engines used in off-road applications such as those typically found in construction, mining, farming and forestry machines. These regulations encompassed the US EPA Tier 2 and Tier 3 standards. In November 2011, the regulations were amended to align with the US EPA Tier 4 standards.

The Off-Road Compression-Ignition Engine Emission Regulations apply to "reciprocating, internal combustion engines, other than those that operate under characteristics significantly similar to the theoretical Otto combustion cycle and that use a spark plug or other sparking device". This definition is not exactly the same as the definition of a diesel engine used in the On-Road Vehicle and Engine Emission Regulations where a diesel engine is defined as one "that has operating characteristics significantly similar to those of the theoretical Diesel combustion cycle. The non-use of a throttle during normal operation is indicative of a diesel engine". The off-road regulations focus on the ignition mechanism while the on-road regulations focus on the load control mechanism in distinguishing the engine type.

The regulations specifically exempt engines:

- designed exclusively for competition

- regulated by the On-Road Vehicle and Engine Emission Regulations;
- designed to be used exclusively in underground mines;
- with a per-cylinder displacement of less than 50 cm^3;
- for military machines used in combat or combat support;
- being exported and not sold or used in Canada;
- designed to be used in a vessel and for which the fuel, cooling and exhaust systems are integral parts of the vessel.

While not specifically exempted by the regulation, Environment Canada does not have legislative authority to regulate emissions from railway locomotive engines.

The Canadian Off-Road Compression-Ignition Engine Emission Regulations do not include an optional averaging, banking and trading program as do the US EPA regulations.

Tier 2/3 Standards. The Canadian Off-Road Compression-Ignition Engine Emission Regulations align the engine certification values with those of the US EPA Tier 2 and Tier 3 values, Table 1. The implementations dates, however, were later. In the US, compliance with Tier 2 requirements was mandatory as early as model year 2001 and with Tier 3 starting with model year 2006. Compliance in Canada with US EPA Tier 2 requirements was not mandatory until the 2006 model year.

Tier 4 Standards. On November 17, 2011, Environment Canada adopted amendments to the Off-Road Compression-Ignition Engine Emission Regulations which align Canadian emission standards with the US EPA Tier 4 standards for non-road engines. The Tier 4 standards come into force on January 16, 2012 and apply to engines of the 2012 and later model years manufactured on and after January 16, 2012.

Table 1
Canadian Tier 2/3 Off-Road Compression-Ignition Engine Emission Standards, g/kWh

Power (P), kW	Tier	Year	NMHC + NO_x	CO	PM
P <8	Tier 2	2006	7.5	8.0	0.80
8≤ P <19	Tier 2	2006	7.5	6.6	0.80
19≤ P <37	Tier 2	2006	7.5	5.5	0.60
37≤ P <75	Tier 2	2006	7.5	5.0	0.40
	Tier 3	2008	4.7	5.0	0.40
75≤ P <130	Tier 2	2006	6.6	5.0	0.30
	Tier 3	2007	4.0	5.0	0.30
130≤ P <225	Tier 3	2006	4.0	3.5	0.20
225≤ P <450	Tier 3	2006	4.0	3.5	0.20
450≤ P <560	Tier 3	2006	4.0	3.5	0.20
P >560	Tier 2	2006	6.4	3.5	0.20

Mining Engines. Emissions from engines used exclusively in underground mining equipment fall under provincial jurisdiction. While emissions from these engines are not directly regulated, provincial regulations exist for ventilation rates in mines were these engines are used. Canadian Standards Association (CSA) standards have been established that describe the technical requirements and procedures necessary for the design, performance, and testing of new or unused non-rail-bound, diesel-powered, self-propelled machines in underground mines (MMSL02-043). Testing carried out according to these CSA standards establish the minimum ventilation rate required for any engine to keep air quality at an acceptable level. Some provinces base their ventilation requirements on the results of testing according to the CSA standards.

Off-Road Small Spark-Ignition Engines

The Off-Road Small Spark-Ignition Engine Emission Regulations were promulgated on November 19, 2003. The Regulations apply to off-road engines of model year 2005 and later that use sparkplugs and develop no more than 19 kW (25 hp) of power. The emissions standards are divided into seven classes based on engine displacement and usage in either a handheld or non-handheld application as shown in Table 2.

Engines must meet the emission standards throughout their useful life (with the exception of pre-2005 Class I engines, as indicated in the table). At the time of engine certification, a manufacturer can select one of three specified useful life periods, which range from 50 to 1000 hours depending on the engine class. For example, for a class I engine, the useful life can be 125, 250 or 500 hours. The selection of useful life duration must be supported by technical information. Longer useful lives, which entail a higher manufacturing cost, are typically found in commercial equipment while home consumer products are often designed for shorter useful lives.

Alternative less stringent emission standards, consistent with those available under the CFR, are available:

- for HC+NO_x levels for engines in machines used exclusively in wintertime, such as ice augers and snow-blowers; These engines are subject to the applicable CO standard.
- for replacement engines which are engines manufactured exclusively to replace an existing engine in a machine for which no current model year engine with physical or performance characteristics necessary for the operation of the machine exists;
- for class III, IV and V when less than 2000 engines of a particular model are sold in total in Canada to accommodate Canada-only niche products.

On February 4, 2011, Environment Canada adopted Marine Spark-Ignition Engine, Vessel and Off-Road Recreational Vehicle Emission Regulations. These emission regulations apply to outboard engines, personal watercraft, snowmobiles, off-highway motorcycles and all-terrain vehicles. Most of the regulatory provisions came into force from April 5, 2011. The standards align with corresponding US EPA rules for marine spark-ignition engines and off-road recreational engines and vehicles. An earlier MOU with the Canadian Marine Manufacturers Association covered only marine spark ignition engines and under its terms,

Table 2
Small Spark-Ignition Engine Emission Standards, g/kWh

Class	Engine Type	Displacement (D), cm^3	Date	HC + NO_x[b]	NMHC + NO_x	CO
I-A	Non-handheld	D <66	2005	50	-	610
I-B		66≤ D <100	2005	40	37	610
I		100≤ D <225	2005[1]	16.1[a]	-	519[a]
			2005[2]	16.1	14.8	610
			2007	16.1	14.8	610
II		D ≥225	2005	12.1	11.3	610
III	Handheld	D <20	2005	50	-	805
IV		20≤ D <50	2005	50	-	805
V		D ≥50	2005	119	-	603
			2006	96	-	603
			2007	72	-	603

a - Standards apply only when the engine is new
b - Some engine classes include a combined NMHC+NO_x standard that applies only when the engine is fueled by natural gas
1 - For models already in production at coming into force of the Regulations
2 - For models initially produced after coming into force of the Regulations

engine manufacturers voluntarily committed to supply engines designed to meet United States federal emissions standards into Canada starting with the 2001 model year.

Environment Canada plans to propose regulations to address emissions from large spark-ignition engines used in industrial applications such as forklifts and ice re-surfacing machines in the future.

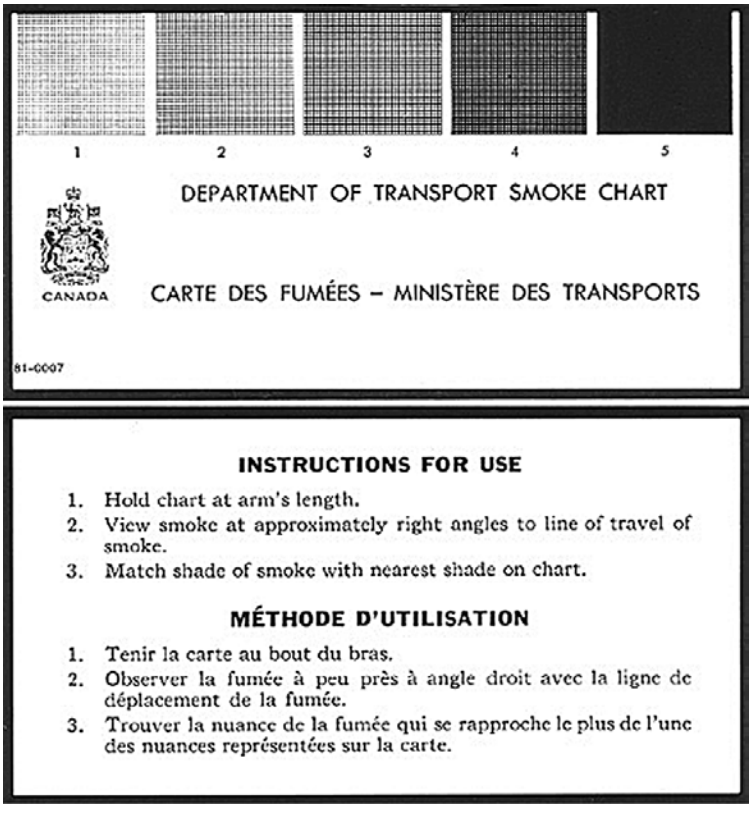
Marine Engines

Authority to regulate emissions from marine propulsion engines smaller than 37 kW falls to Environment Canada. The Off-Road Compression-Ignition Engine Emission Regulations cover compression ignition marine engines less than 37 kW. Regulations are planned for marine spark-ignition engines.

Transport Canada has authority to regulate emissions from marine propulsion engines larger than 37 kW. Current emission standards from ships are under the authority of Transport Canada. The Air Pollution Regulations of the Canada Shipping Act regulates the density of black smoke from ships in Canadian waters and within 1 mile of land. Smoke density rating is determined by the Department of Transport Smoke Chart set out in the schedule of the regulations and reproduced below. For vessels with diesel engines a smoke density less than No. 1 is normally required with the exception that a smoke density of No. 2 for an aggregate of not more than 4 minutes in any 30-minute period is allowed.

Pollution Prevention Regulations under the Canada Shipping Act are under development to align with IMO MARPOL 73/78 Annex VI. This agreement sets limits for NO_x emissions from marine engines with power outputs more than 130 kW that have either been installed on a ship constructed on or after January 1, 2000 or have had major conversions on or after January 1, 2000.

Figure 1. Smoke Density Chart



On-Road Vehicles And Engines

Background

Mexican emission requirements for new vehicles and engines are adopted by the *Secretaria de Medio Ambiente y Recursos Naturales (SEMARNAT)*. Emission compliance is generally required with either the US or European emission standards.

First emission standards for both light- and heavy-duty vehicles were established on 6 June 1988 and became effective in model year 1993 [NOM-044-ECOL-1993]. The light-duty standards were later strengthened to be equivalent to the US Tier 1, effective 2001 [NOM-042-ECOL-1999]. A mix of US Tier 1/2 and Euro 3/4 standards is required since 2004 [NOM-042-SEMARNAT-2003].

New emission requirements for heavy-duty truck and bus engines were adopted on 12 October 2006, which require compliance with US 2004 or Euro IV equivalent standards effective July 2008 [NOM-044-SEMARNAT-2006].

Light-Duty Vehicle Classification

Light duty vehicles are defined as vehicles of GVW ≤ 3857 kg. Passenger cars (PC) are defined as vehicles with up to 10 seats, including the driver. Light trucks are classified in four groups — corresponding to the US Light Duty Truck 1 to 4 — based on the GVW and the test weight (weight of the vehicle with full fuel tank) as follows:

- CL1: GVW ≤ 2722 kg, test weight ≤ 1701 kg
- CL2: GVW ≤ 2722 kg, test weight 1701 - 2608 kg
- CL3: GVW 2722 - 3857 kg, test weight ≤ 2608 kg
- CL4: GVW 2722 - 3857 kg, test weight 2608 - 3857 kg

Weight ratings based on the European grouping for passenger cars and light commercial vehicles using a vehicle's reference mass (weight of vehicle with full tank of fuel + 100 kg) are also used:

- CL Class 1: reference mass ≤ 1305 kg
- CL Class 2: reference mass > 1305 kg but ≤ 1760 kg
- CL Class 3: reference mass > 1760 kg

Model Year 1993-2003

Emission standards for light-duty vehicles are summarized in Table 1. The standards were based on the US regulations and test methods (FTP-75). The 1993 requirements were based on the US 1981 emission standards. The 2001 requirements represent the US Tier 1 standards *without OBD II provisions*.

The standards apply both to gasoline and diesel vehicles, with the exception of NO_x standards, as specified, and the PM standard that applies only to diesels. Natural gas and LPG vehicles have the same standards as gasoline vehicles.

Table 1
Emission Standards for Cars and Light-Duty Trucks, g/km

Year	CO	NMHC*	NO_x		PM†
			Gasoline	Diesel	
Passenger Cars					
1993	2.11	0.25	0.62	0.62	0.07
2001	2.11	0.156	0.25	0.62	0.07
Light Trucks CL1					
1994	8.75	0.63	1.44	1.44	0.07
2001	2.11	0.156	0.25	0.62	0.07
Light Trucks CL2					
1994	8.75	0.63	1.44	1.44	0.07
2001	2.74	0.20	0.44	0.62	0.07
Light Trucks CL3					
1994	8.75	0.63	1.44	1.44	0.07
2001	2.74	0.20	0.44	0.62	0.07
Light Trucks CL4					
1994	8.75	0.63	1.44	1.44	0.10
2001	3.11	0.24	0.68	0.62	0.10

* total hydrocarbons (THC) prior to model-year 2001
† diesel vehicles only

Gasoline, natural gas, and LPG vehicles of all classes and all model years must also meet an evaporative (SHED) limit of 2 g/test.

Model Year 2004 And Later

The model year 2004 and later standards are based on US Tier 1 and Tier 2 standards and Euro 3 and Euro 4 limits. New vehicles must meet the standards set out in either Table 2 (based on US Tier 1/2 limits) or Table 3 (based on Euro 3/4 limits). Vehicles meeting these standards are also required to be equipped with OBD.

Table 2
Light-Duty Vehicle Emission Limit Option Based on US EPA Standards, g/km

Standard	Class	CO		NMHC		NO_x		PM	
		Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
A	PC	2.11		0.156		0.25	0.62	n/a	0.050
	CL1								
	CL2	2.74		0.200		0.44	0.62		0.062
	CL3								
	CL4	3.11		0.240		0.68	0.95		0.075
B	PC	2.11		0.099		0.249 0.062 0.075		n/a	0.050
	CL1								
	CL2								
	CL3	2.74		0.121					
	CL4								
C	PC	2.11		0.047		0.068 0.062		n/a	0.050
	CL1								
	CL2								
	CL3		0.087		0.124 0.075				
	CL4								

Table 3
Light-Duty Vehicle Emission Limit Option Based on European Standards, g/km

Standard	Class	CO		NMHC		NOx		PM	
		Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
B	PC	1.25	0.64	0.125	0.56	0.100	0.50	n/a	0.050
	CL Class 1								
	CL Class 2	2.26	0.80	0.162	0.72	0.125	0.65		0.070
	CL Class 3	2.83	0.95	0.200	0.86	0.137	0.78		0.100
C	PC	1.00	0.50	0.10	0.30	0.08	0.25	n/a	0.050
	CL Class 1								
	CL Class 2	1.81	0.63	0.13	0.39	0.10	0.33		0.040
	CL Class 3	2.27	0.74	0.16	0.46	0.11	0.39		0.060

Notes to Table 2 and Table 3:

1. Emission durability requirements:
   - 80,000 km / 50,000 mi for US EPA option (Table 2), or
   - 100,000 km for European option (Table 3)
2. Gasoline vehicle standards also apply to natural gas and LPG vehicles.
3. Gasoline, natural gas, and LPG vehicles of all classes and all model years must also meet an evaporative (SHED) limit of 2 g/test.

An important factor in the phase-in of these vehicles is the introduction of gasoline with 30 ppm average and 80 ppm maximum sulfur, and diesel fuel with 15 ppm sulfur. The calendar year that these fuels become available nationally is referred to as "Year 1" (Año 1). It is expected to be 2009, according to Mexican fuel quality regulations [NOM-086-SEMARNAT-SENER-SCFI-2005]. Vehicles meeting the "A" standard in Table 2 are those produced between 2004 to 2009. Vehicles meeting "B" standard in Table 2 and Table 3 are those produced from 2007 to "Year 3"— 2 calendar years after "Year 1". Vehicles meeting "C" standard in in Table 2 and Table 3 are those produced starting in "Year 1". The phase-in schedules for vehicles meeting B and C standards are laid out in Table 4 and Table 5, respectively.

Table 4
Phase-In Schedule of Light-Duty Vehicles Meeting B Standards

Standard	2007	2008	2009	2010
A	75%	50%	30%	0%
B	25%	50%	70%	100%

Table 5
Phase-In Schedule of Light-Duty Vehicles Meeting C Standards

Standard	Year 1	Year 2	Year 3	Year 4
A+B	75%	50%	30%	0%
C	25%	50%	70%	100%

Table 6 Emission Requirements for Diesel Truck and Bus Engines		
Date	Requirements	
	US EPA	European
1993	US 1991	
1994	US 1994	
1998	US 1998	
2003.02	US 1998	Euro III
2008.07†	US 2004	Euro IV
† Through 2011.06; later requirements are not specified.		

While the standards in Table 2 and Table 3 are based on US EPA limits and European limits, they are not necessarily structured the same way. For example, the NO_x and PM limits defined by the "A" standard in Table 2 are a combination of 50,000 mile and full useful life US EPA Tier 1 limits. For the "B" and "C" standards, the PM limits do not change, (i.e., they stay at the Tier 1 limits) while the NO_x standards decrease to limits based on 50,000 mile US EPA Tier 2 values. The NO_x limit for the "B" standard is US Tier 2 Bin 10 and for the "C" standard is Bin 7 (for lighter vehicles) and Bin 9 (for heavier vehicles). With the exception of "B" standard for gasoline, LPG and natural gas, the standards in Table 3 are equivalent to Euro 3 and 4 limits. Note the different durability requirements for the standards in Table 2 (80,000 km) and Table 3 (100,000 km).

Heavy-Duty Trucks and Buses

Emission standards for new heavy-duty diesel engines — applicable to vehicles of GVW > 3,857 kg — became first effective in model year 1993. These standards were based on US 1991 and later requirements, including the US EPA test methods (FTP transient test).

Since February 2003, engines in Mexico can also meet European standards, as an alternative to the US EPA requirements. The US EPA or European reference standard requirements are summarized in Table 6.

No emission standards were adopted for gasoline fueled trucks and buses.

Emissions Standards: European Union
Heavy-Duty Diesel Truck And Bus Engines

Regulatory Framework

European emission regulations for new heavy-duty diesel engines are commonly referred to as Euro I ... VI. Sometimes Arabic numerals are also used (Euro 1 ... 6). We will use Roman numerals when referencing standards for heavy-duty engines, and reserve Arabic numerals for light-duty vehicle standards.

The emission standards apply to all motor vehicles with a "technically permissible maximum laden mass" over 3,500 kg, equipped with compression ignition engines or positive ignition natural gas (NG) or LPG engines.

The regulations were originally introduced by the *Directive 88/77/EEC*, followed by a number of amendments. In 2005, the regulations were re-cast and consolidated by the *Directive 05/55/EC*. Beginning with the Euro VI stage, the legislation became simplified, as "directives"— which need to be transposed into all of the national legislations — were replaced by "regulations" which are directly applicable. The following are some of the most important rulemaking steps in the heavy-duty engine regulations:

- Euro I standards were introduced in 1992, followed by the introduction of Euro II regulations in 1996. These standards applied to both truck engines and urban buses, the urban bus standards, however, were voluntary.

- In 1999, the EU adopted *Directive 1999/96/EC*, which introduced Euro III standards (2000), as well as Euro IV/V standards (2005/2008). This rule also set voluntary, stricter emission limits for extra low emission vehicles, known as "enhanced environmentally friendly vehicles" or EEVs.

- In 2001, the European Commission adopted *Directive 2001/27/EC* which prohibits the use of emission "defeat devices" and "irrational" emission control strategies, which would be reducing the efficiency of emission control systems when vehicles operate under normal driving conditions to levels below those determined during the emission testing procedure.

- *Directive 2005/55/EC* adopted by the EU Parliament in 2005 introduced durability and OBD requirements, as well as re-stated the emission limits for Euro IV and Euro V which were originally published in 1999/96/EC. In a "split-level" regulatory approach, the technical requirements pertaining to durability and OBD — including provisions for emission systems that use consumable reagents — have been described by the Commission in *Directive 2005/78/EC*.

- Euro VI emission standards were introduced by *Regulation 595/2009* published on 18 July 2009 (with a Corrigenda of 31 July 2009). The new emission limits, comparable in stringency to the US 2010 standards, become effective from 2013 (new type approvals) and 2014 (all registrations). In the "split-level" approach, a number of technical details will be specified in the implementing regulation ('comitology') which should be adopted by the end of 2010.

Emission Standards

Table 2 contains a summary of the emission standards and their implementation dates. Dates in the tables refer to new type approvals; the dates for all type approvals are in most

cases one year later (EU type approvals are valid longer than one year).

Table 1
EU Emission Standards for HD Diesel Engines, g/kWh (smoke in m^{-1})

Tier	Date	Test	CO	HC	NO_x	PM	Smoke
Euro I	1992, < 85 kW	ECE R-49	4.5	1.1	8.0	0.612	
	1992, > 85 kW		4.5	1.1	8.0	0.36	
Euro II	1996.10		4.0	1.1	7.0	0.25	
	1998.10		4.0	1.1	7.0	0.15	
Euro III	*1999.10, EEVs only*	*ESC & ELR*	*1.5*	*0.25*	*2.0*	*0.02*	*0.15*
	2000.10	ESC & ELR	2.1	0.66	5.0	0.10 0.13[a]	0.8
Euro IV	2005.10		1.5	0.46	3.5	0.02	0.5
Euro V	2008.10		1.5	0.46	2.0	0.02	0.5
Euro VI	2013.01		1.5	0.13	0.4	0.01	

a - for engines of less than 0.75 dm^3 swept volume per cylinder and a rated power speed of more than 3000 min^{-1}

Since the Euro III stage (2000), the earlier steady-state engine test ECE R-49 has been replaced by two cycles: the European Stationary Cycle (ESC) and the European Transient Cycle (ETC). Smoke opacity is measured on the European Load Response (ELR) test. The following testing requirements apply:

Table 2
Emission Standards for Diesel and Gas Engines, ETC Test, g/kWh

Tier	Date	Test	CO	NMHC	CH_4[a]	NO_x	PM[b]
Euro III	*1999.10, EEVs only*	*ETC*	*3.0*	*0.40*	*0.65*	*2.0*	*0.02*
	2000.10	ETC	5.45	0.78	1.6	5.0	0.16 0.21[c]
Euro IV	2005.10		4.0	0.55	1.1	3.5	0.03
Euro V	2008.10		4.0	0.55	1.1	2.0	0.03
Euro VI	2013.01		4.0	0.16[d]	0.5	0.4	0.01

a - for gas engines only (Euro III-V: NG only; Euro VI: NG + LPG)
b - not applicable for gas fueled engines at the Euro III-IV stages
c - for engines with swept volume per cylinder < 0.75 dm^3 and rated power speed > 3000 min^{-1}
d - THC for diesel engines

1. Compression ignition (diesel) engines:

- Euro III:
  - i. Conventional diesel engines: ESC/ELR test
  - ii. Diesel engines with "advanced aftertreatment" (NO_x aftertreatment or DPFs) and EEVs: ESC/ELR + ETC
- Euro IV and later: ESC/ELR + ETC

2. Positive ignition gas (natural gas, LPG) engines, Euro III and later: ETC cycle

Emission standards for diesel engines that are tested on the ETC test cycle, as well as for heavy-duty gas engines, are summarized in Table 2.

Euro VI Regulation. Additional provisions of the Euro VI regulation include:

- An ammonia (NH_3) concentration limit of 10 ppm applies to diesel (ESC + ETC) and gas (ETC) engines.
- A particle number limit, in addition to the mass limit, is to be introduced in the implementing regulation. The number limit would prevent the possibility that the Euro VI PM mass limit is met using technologies (such as "open filters") that would enable a high number of ultra fine particles to pass.
- The world-harmonized test cycles — WHSC and WHTC — will be used for Euro VI testing. WHSC/WHTC based limit values will be introduced by the implementing regulation based on correlation factors with the current ESC/ETC tests.
- A maximum limit for the NO_2 component of NO_x emissions may be defined in the implementing regulation.

Emission Durability. Effective October 2005 for new type approvals and October 2006 for all type approvals, manufacturers should demonstrate that engines comply with the emission limit values for useful life periods which depend on the vehicle category, as shown in Table 3.

Effective October 2005 for new type approvals and October 2006 for all type approvals, type approvals also require confirmation of the correct operation of the emission control devices during the normal life of the vehicle under normal conditions of use ("conformity of in-service vehicles properly maintained and used").

Early Introduction of Clean Engines. EU Member States are allowed to use tax incentives in order to speed up the marketing of vehicles meeting new standards ahead of the regulatory deadlines. Such incentives have to comply with the following conditions:

Table 3 Emission Durability Periods		
Vehicle Category†	Period*	
	Euro IV-V	Euro VI
N1 and M2	100 000 km / 5 years	160 000 km / 5 years
N2 N3 ≤ 16 ton M3 Class I, Class II, Class A, and Class B ≤ 7.5 ton	200 000 km / 6 years	300 000 km / 6 years
N3 > 16 ton M3 Class III, and Class B > 7.5 ton	500 000 km / 7 years	700 000 km / 7 years
† Mass designations (in metric tons) are "maximum technically permissible mass" * km or year period, whichever is the sooner		

- they apply to all new vehicles offered for sale on the market of a Member State which comply in advance with the mandatory limit values set out by the Directive,
- they cease when the new limit values come into effect
- for each type of vehicle they do not exceed the additional cost of the technical solutions introduced to ensure compliance with the limit values.

Euro VI type approvals, if requested, must be granted from 7 August 2009, and incentives can be given from the same date. Euro VI incentives can also be given for scrapping existing vehicles or retrofitting them with emission controls in order to meet Euro VI limits.

Early introduction of cleaner engines can be also stimulated by such financial instruments as preferential road toll rates. In Germany, road toll discounts were introduced in 2005 which stimulated early launch of Euro V trucks.

Emissions Standards: European Union
Nonroad Diesel Engines

Background

The European emission standards for new nonroad diesel engines have been structured as gradually more stringent tiers known as Stage I-IV standards. Additionally, emission standards have been adopted for small, gasoline fueled nonroad engines. The main regulatory steps were:

- Stage I/II. The first European legislation to regulate emissions from nonroad (off-road) mobile equipment was promulgated on December 16, 1997 *[Directive 97/68/EC]*. The regulations for nonroad diesels were introduced in two stages: Stage I implemented in 1999 and Stage II implemented from 2001 to 2004, depending on the engine power output.

The equipment covered by the standard included industrial drilling rigs, compressors, construction wheel loaders, bulldozers, nonroad trucks, highway excavators, forklift trucks, road maintenance equipment, snow plows, ground support equipment in airports, aerial lifts and mobile cranes. Agricultural and forestry tractors had the same emission standards but different implementation dates *[Directive 2000/25/EC]*. Engines used in ships, railway locomotives, aircraft, and generating sets were not covered by the Stage I/II standards.

- On December 9, 2002, the European Parliament adopted Directive 2002/88/EC, amending the nonroad *Directive 97/68/EC* by adding emission standards for small, gasoline fueled utility engines below 19 kW. The Directive also extended the applicability of Stage II standards on constant speed engines. The utility engine emission standards are to a large degree aligned with the US emission standards for small utility engines.
- Stage III/IV. Stage III/IV emission standards for nonroad engines were adopted by the European Parliament on 21 April 2004

Table 1 EU Stage I/II Emission Standards for Nonroad Diesel Engines						
Cat.	Net Power	Date*	CO	HC	NO_x	PM
	kW		g/kWh			
Stage I						
A	130 ≤ P ≤ 560	1999.01	5.0	1.3	9.2	0.54
B	75 ≤ P < 130	1999.01	5.0	1.3	9.2	0.70
C	37 ≤ P < 75	1999.04	6.5	1.3	9.2	0.85
Stage II						
E	130 ≤ P ≤ 560	2002.01	3.5	1.0	6.0	0.2
F	75 ≤ P < 130	2003.01	5.0	1.0	6.0	0.3
G	37 ≤ P < 75	2004.01	5.0	1.3	7.0	0.4
D	18 ≤ P < 37	2001.01	5.5	1.5	8.0	0.8
* Stage II also applies to constant speed engines effective 2007.01						

[Directive 2004/26/EC], and for agricultural and forestry tractors on 21 February 2005 *[Directive 2005/13/EC]*.

Two additional Directives were adopted in 2010: *Directive 2010/26/EU* provides further technical details on the testing and approvals of Stage IIIB and Stage IV engines, and *Directive 2010/22/EU* amends the earlier legislation applicable to agricultural and forestry tractors.

Stage III standards — which are further divided into Stages IIIA and IIIB — are phased-in from 2006 to 2013, Stage IV enter into force in 2014. The Stage III/IV standards, in addition to the engine categories regulated at Stage I/II, also cover railroad locomotive engines and marine engines used for inland waterway vessels. Stage III/IV legislation applies only to new vehicles and equipment; replacement engines to be used in machinery already in use (except for railcar, locomotive and inland waterway vessel propulsion engines) should comply with the limit values that the engine to be replaced had to meet when originally placed on the market.

EU nonroad emission standards usually specify two sets of implementation dates:

- *Type approval* dates, after which all newly type approved models must meet the standard, and
- *Market placement* (or first registration) dates, after which all new engines placed on the market must meet the standard.

The dates listed in the following tables are the market placement dates. In most cases, new type approval dates are one year before the respective market placement dates.

Regulatory authorities in the EU, USA, and Japan have been under pressure from engine and equipment manufacturers to harmonize worldwide emission standards, in order to streamline engine development and emission type approval/certification for different markets. Stage I/II limits were in part harmonized with US regulations. Stage III/IV limits are harmonized with the US Tier 3/4 standards.

Stage I/II Standards

Stage I and Stage II emissions shall not exceed the amount shown in Table 1. The Stage I emissions are engine-out limits and shall be achieved before any exhaust aftertreatment device.

A sell-off period of up to two years is allowed for engines produced prior to the respective market placement date. Since the sell-off period — between zero and two years — is determined by each Member State, the exact timeframe of the regulations may be different in different countries.

Table 2
Stage III A Standards for Nonroad Engines

Cat.	Net Power	Date†	CO	NO_x+HC	PM
	kW		g/kWh		
H	130 ≤ P ≤ 560	2006.01	3.5	4.0	0.2
I	75 ≤ P < 130	2007.01	5.0	4.0	0.3
J	37 ≤ P < 75	2008.01	5.0	4.7	0.4
K	19 ≤ P < 37	2007.01	5.5	7.5	0.6

† dates for constant speed engines are: 2011.01 for categories H, I and K; 2012.01 for category J.

Table 3
Stage III B Standards for Nonroad Engines

Cat.	Net Power	Date	CO	HC	NO_x	PM
	kW		g/kWh			
L	130 ≤ P ≤ 560	2011.01	3.5	0.19	2.0	0.025
M	75 ≤ P < 130	2012.01	5.0	0.19	3.3	0.025
N	56 ≤ P < 75	2012.01	5.0	0.19	3.3	0.025
P	37 ≤ P < 56	2013.01	5.0	4.7†		0.025

† NO_x+HC

Table 4
Stage IV Standards for Nonroad Engines

Cat.	Net Power	Date	CO	HC	NO_x	PM
	kW		g/kWh			
Q	130 ≤ P ≤ 560	2014.01	3.5	0.19	0.4	0.025
R	56 ≤ P < 130	2014.10	5.0	0.19	0.4	0.025

Emissions are measured on the ISO 8178 C1 8-mode cycle and expressed in g/kWh. Stage I/II engines are tested using fuel of 0.1-0.2% (wt.) sulfur content.

Stage III/IV Standards

Stage III standards — which are further divided into two sub-stages: Stage III A and Stage III B — and Stage IV standards for nonroad diesel engines are listed in Table 2, Table 3, and Table 4, respectively. These limit values apply to all nonroad diesel engines of indicated power range for use in applications other than propulsion of locomotives, railcars and inland waterway vessels.

The implementation dates in the following tables (Table 2 through Table 7) refer to the market placement dates. For all engine categories, a sell-off period of two years is allowed for engines produced prior to the respective *market placement* date. The dates for *new type approvals* are, with some exceptions, one year ahead of the respective market placement date.

Stage III/IV standards also include a limit for ammonia emissions, which must not exceed a mean of 25 ppm over the test cycle.

Stage III B standards introduce PM limit of 0.025 g/kWh, representing about 90% emission reduction relative to Stage II. To meet this limit value, it is anticipated that engines will have to be equipped with particulate filters. Stage IV also introduces a very stringent NO_x limit of 0.4 g/kWh, which is expected to require NO_x aftertreatment.

To represent emissions during real conditions, a new transient test procedure — the Non-Road Transient Cycle (NRTC) — was developed in cooperation with the US EPA. The NRTC is run twice — with a cold and a hot start. The final emission results are weighted averages of 10% for the cold start and 90% for the hot start run. The new test will be used in parallel with the prior steady-state schedule, ISO 8178 C1, referred to as the Non-Road Steady Cycle (NRSC).

- The NRSC (steady-state) shall be used for stages I, II and III A, as well as for constant speed engines at all stages. The NRTC (transient) can be used for Stage III A testing by the choice of the manufacturer.

- Both NRSC and NRTC cycles shall be used for Stage III B and IV testing (gaseous and particulate pollutants).

Inland Water Vessels

Unlike the Stage I/II legislation, the Stage III A standards also cover engines used in inland waterway vessels, Table 5. Engines are divided into categories based on the displacement (swept volume) per cylinder and net power output. The engine categories and the standards are harmonized with the US standards for marine engines. There are no Stage III B or Stage IV standards for waterway vessels.

Table 5
Stage III A Standards for Inland Waterway Vessels

Cat.	Displacement (D)	Date	CO	NO_x+HC	PM
	dm^3 per cylinder		g/kWh		
V1:1	D ≤ 0.9, P > 37 kW	2007.01	5.0	7.5	0.40
V1:2	0.9 < D ≤ 1.2		5.0	7.2	0.30
V1:3	1.2 < D ≤ 2.5		5.0	7.2	0.20
V1:4	2.5 < D ≤ 5	2009.01	5.0	7.2	0.20
V2:1	5 < D ≤ 15		5.0	7.8	0.27
V2:2	15 < D ≤ 20, P ≤ 3300 kW		5.0	8.7	0.50
V2:3	15 < D ≤ 20, P > 3300 kW		5.0	9.8	0.50
V2:4	20 < D ≤ 25		5.0	9.8	0.50
V2:5	25 < D ≤ 30		5.0	11.0	0.50

Rail Traction Engines

Stage III A and III B standards have been adopted for engines above 130 kW used for the propulsion of railroad locomotives (categories R, RL, RH) and railcars (RC), Table 6 and Table 7.

Table 6
Stage III A Standards for Rail Traction Engines

Cat.	Net Power	Date	CO	HC	HC+NO_x	NO_x	PM
	kW		g/kWh				
RC A	130 < P	2006.01	3.5	-	4.0	-	0.2
RL A	130 ≤ P ≤ 560	2007.01	3.5	-	4.0	-	0.2
RH A	P > 560	2009.01	3.5	0.5*	-	6.0*	0.2

* HC = 0.4 g/kWh and NO_x = 7.4 g/kWh for engines of P > 2000 kW and D > 5 liters/cylinder

Table 7 Stage III B Standards for Rail Traction Engines							
Cat.	Net Power	Date	CO	HC	HC+NO_x	NO_x	PM
	kW		g/kWh				
RC B	130 < P	2012.01	3.5	0.19	-	2.0	0.025
R B	130 < P	2012.01	3.5	-	4.0	-	0.025

Emissions Standards: Germany
Stationary Engines — TA Luft

Background

The *Technische Anleitung zur Reinhaltung der Luft*, in short referred to as *TA Luft*, is a regulation covering air quality requirements — including emissions, ambient exposures and their control methods — applicable to a number of pollutants from a range of stationary sources. The TA Luft regulation, based on the "Federal Air Pollution Control Act" *("Bundes-Immissionsschutzgesetz")*, has been introduced and is enforced by the German Environment Ministry BMU *(Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit)*.

Among other sources, the TA Luft regulation covers emissions of pollutants from stationary internal combustion engines. The TA Luft requirements have been widely applied to stationary gas and diesel engines not only in Germany, but also in several other European markets.

The TA Luft regulation was first introduced in 1986. The most recent revision, known as *TA Luft 2002*, was adopted on 24 July 2002. Compared to the previous requirements, TA Luft 2002 has introduced more stringent emission limits for particulate matter, sulfur oxides, and nitrogen oxides from internal combustion engines.

Engine Emission Standards

TA Luft 2002 emission limits for PM, CO, and NO_x are given in Tables 1-3. Different limits exist for compression ignition (CI) and for spark ignited (SI) engines. Gas fueled CI engines (dual fuel with diesel pilot ignition) often enjoy more relaxed limits, especially if fueled by biogas (such as sewage or landfill gas).

All of the above engine emission limits are expressed as dry gas concentrations at STP conditions, that have been corrected to a 5% oxygen content using the following formula:

$$EB = EM \times (21 - OB)/(21 - OM)$$

where:

EB - mass concentration of pollutant corrected for the reference O_2 concentration,
EM - measured mass concentration of pollutant,
OB - reference O_2 concentration, vol. %,
OM - measured O_2 concentration, vol. %.

The TA Luft 2002 limits for diesel engines are rather strict.

Table 1 PM Emission Limits for Internal Combustion Engines, mg/Nm³ @ 5% O_2	
Category	PM
CI liquid fueled	20
CI liquid fueled stand-by[a]	80
CI gas fueled (dual fuel) or SI	no limit
a - emergency operation only or peak shaving operation for less than 300 hrs per year	

Table 2 CO Emission Limits for Internal Combustion Engines, g/Nm³ @ 5% O_2		
Category	CO†	
	≥ 3 MW	< 3 MW
All, excluding biogas and mine gas fueled	0.3	
CI biogas (dual fuel)	0.65	2.0
SI biogas	0.65	1.0
SI mine gas	0.65	
† CO limits do not apply to emergency engines or engines used for peak shaving for less than 300 hrs per year		

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Table 3 NO_x Emission Limits for Internal Combustion Engines, g/Nm³ @ 5% O_2		
Category	**NO_x†**	
	≥ 3 MW	**< 3 MW**
CI liquid fueled CI biogas (dual fuel)	0.5	1.0
SI biogas or SI lean-burn using other gas fuels CI (dual fuel) using other gas fuels	0.5	
Other 4-stroke Otto engines	0.25	
2-stroke engines	0.8	
† NO_x limits do not apply to emergency engines or engines used for peak shaving for less than 300 hrs per year		

The NO_x limit of 0.5 g/Nm³ typically requires the use of SCR catalysts on large diesel engines.

Sulfur Regulations. According to TA Luft 2002, a liquid fired stationary engine is to burn a light fuel oil according to DIN 51603 Part 1 (March 1998) containing max. 0.2% (wt.) sulfur and with a lower heating value > 42.6 MJ/kg, or to reach an equivalent SO_2 limit by installing a flue gas desulfurization unit. The equivalent SO_2 limit resulting from the above fuel requirement is about 110 mg/Nm³ @ 15% O_2 = approx. 300 mg/Nm³ @ 5% O_2.

Emissions Standards: Russia
All Vehicles Categories

Light-Duty Vehicles

Russia adopts European emission standards, which apply to both manufactured and imported vehicles. Implementation dates are listed in Table 1.

Table 1 Emission Requirements for Light-Duty Vehicles	
Date	**Requirement**
1999.01	Euro 1 (ECE R83.02)
2006.04	Euro 2 (ECE R83.03)
2008.01	Euro 3 (ECE R83.05 Stage III)
2010.01	Euro 4 (ECE R83.05 Stage IV)
2014.01	Euro 5

Heavy-Duty Engines

Heavy-duty highway engines are required to meet European emission standards. The implementation schedule is outlined in Table 2.

Table 2 Emission Requirements for Heavy-Duty Engines	
Date	**Requirement**
1999.01	Euro I / Ecological Class 1 (ECE R49.02)
2006.01	Euro II / Ecological Class 2 (ECE R49.02 Stage 2)
2008.01	Euro III / Ecological Class 3 (ECE R49.04-A)
2010.01	Euro IV / Ecological Class 4 (ECE R49.04-B1)
2014.01	Euro V / Ecological Class 5 (ECE R49.04-B2 C)

Nonroad Engines

Russia adopts European emission standards for mobile nonroad engines. Current requirements are shown in Table 3.

Table 3 Emission Requirements for Mobile Nonroad Engines	
Standard	**EU Equivalent**
GOST R41 96-99	Stage I (Dir 77/537/EC and Dir 97/68/EC, ECE R24 test)

Fuel Quality

According to the "Technical rules on the Requirements for Automobile and Aviation Fuel, Diesel and Ship Fuel, Fuel for Reactive Engines and Heating Oil" (with amendments delaying the requirements), low sulfur diesel fuels are phased-in based on the following schedule:

- Euro 2 fuel is required from 31 December 2012,
- Euro 3 fuel (equivalent to EN 590:1999 with max 350 ppm sulfur) is required from 31 December 2014,
- Euro 4 fuel (equivalent to EN 590:2004 with max 50 ppm sulfur) is required from 31 December 2015,
- The state may order lower standard fuel for defense purposes. Fuels from the state reserve can be sold for five more years.

Emissions Standards: Turkey
Nonroad Diesel Engines

Emission standards for nonroad engines are adopted by the Turkish Ministry of Industry and Trade. The standards are fully harmonized with the EU regulations, but implementation dates are different, as outlined in the following table. All the implementation dates are market placement dates.

Table 1
Turkish Emission Standards for Nonroad Diesel Engines

Stage	Power (P), kW	Date
Mobile Nonrod Engines		
Stage I (Faz I)	37 ≤ P ≤ 560	2003.04
Stage II (Faz II)	18 ≤ P ≤ 560	2007
Stage IIIA (Faz IIIA)	19 ≤ P ≤ 560	2010
Stage IIIB (Faz IIIB)	130 ≤ P ≤ 560	2011
	56 ≤ P < 130	2012
	37 ≤ P < 56	2013
Stage IV (Faz IV)	130 ≤ P ≤ 560	2014
	56 ≤ P < 130	2014.10
Inland Waterway Vessels		
Stage IIIA (Faz IIIA)	37 ≤ P	2010
Rail Engines		
Stage IIIA (Faz IIIA)	130 ≤ P	2010
Stage IIIB (Faz IIIB)	130 ≤ P	2012

Emissions Standards: Japan
New Engines And Vehicles

Regulatory Authorities

Japanese emission standards for engines and vehicles and fuel efficiency targets are jointly developed by a number of government agencies, including:

- Ministry of the Environment (MOE),
- Ministry of Land, Infrastructure and Transport (MLIT) and
- Ministry of Economy, Trade and Industry (METI)

In developing engine emission standards and policies, the Ministry of the Environment relies on recommendations of its advisory body known as the Central Environment Council (CEC).

Engine and vehicle emission standards are developed under the authority of the "Air Pollution Control Law", while fuel efficiency targets are adopted under the "Law Concerning the Rational Use of Energy" (Energy Conservation Law).

On-Road Engines and Vehicles

Japan introduced fist new engine emissions standards for on-road vehicles in the late 1980's. The Japanese standards, however, remained relaxed through the 1990's. In 2003 the MOE finalized very stringent 2005 emission standards for both light and heavy vehicles. At the time they came to power, the 2005 heavy-duty emission standards (NO_x = 2 g/kWh, PM = 0.027 g/kWh) were the most stringent diesel emission regulation in the world. Effective 2009, these limits are further tightened (NO_x = 0.7 g/kWh, PM = 0.01 g/kWh) to a level in-between the US 2010 and Euro V requirements.

Most categories of onroad vehicles, including passenger cars and heavy-duty trucks and buses, are also subject to mandatory fuel efficiency targets. The Japanese fuel efficiency requirements for heavy trucks and buses were the world's first fuel economy regulation for heavy vehicles.

Off-Road Engines

First emission regulations for new off-road engines and vehicles, known as MOT/MOC standards, were adopted by the former Ministry of Transport (MOT) and Ministry of Construction (MOC).

After the reorganization of Japanese government in 2001, off-road engine emissions fell under the jurisdiction of MOE and MLIT, the same ministries that are responsible for regulating emissions from highway engines. First MOE/MLIT standards for off-road engines were promulgated in 2005.

Marine Engines

In 2003, the MLIT proposed emission regulations for new and existing ocean-going ships. The regulations, aligned with the 1997 MARPOL 73/78 Annex VI limits (by International Maritime Organization), require cutting NO_x emissions by about 10% from previous non-regulated levels.

Emissions Standards: Japan
In-Use Vehicle Regulations

Automotive NO_x and PM Law

In 1992, to cope with NO_x pollution from existing vehicle fleets the MOE adopted the Motor Vehicle NO_x Law, which aimed at the elimination of the oldest, most polluting vehicles from in-use fleets in certain geographical areas. In 2001, the regulation has been amended to also include PM emission requirements, and renamed as Automotive NO_x and PM Law.

Tokyo Retrofit Program

The Tokyo government and several neighboring prefectures adopted diesel emission regulations, which require retrofitting of older in-use diesel vehicles with PM control devices (catalytic converters or particulate filters), or else replacing them with newer, cleaner models. The Tokyo retrofit requirements became effective in October 2003.

Emissions Standards: Japan
On-Road Vehicles And Engines

Table 1
Diesel Emission Standards for Light Commercial Vehicles
GVW ≤ 3500 kg (≤ 2500 kg before 2005)

Vehicle Weight*	Date	Test	Unit	CO	HC	NO_x	PM
				mean (max)	mean (max)	mean (max)	mean (max)
≤ 1700 kg	1988	10-15 mode	g/km	2.1 (2.7)	0.40 (0.62)	0.90 (1.26)	
	1993			2.1 (2.7)	0.40 (0.62)	0.60 (0.84)	0.20 (0.34)
	1997			2.1 (2.7)	0.40 (0.62)	0.40 (0.55)	0.08 (0.14)
	2002			0.63	0.12	0.28	0.052
	2005[b]	JC08[c]		0.63	0.024[d]	0.14	0.013
	2009			0.63	0.024[d]	0.08	0.005
> 1700 kg	1988	6 mode	ppm	790 (980)	510 (670)	DI: 380 (500) IDI: 260 (350)	
	1993	10-15 mode	g/km	2.1 (2.7)	0.40 (0.62)	1.30 (1.82)	0.25 (0.43)
	1997[a]			2.1 (2.7)	0.40 (0.62)	0.70 (0.97)	0.09 (0.18)
	2003			0.63	0.12	0.49	0.06
	2005[b]	JC08[c]		0.63	0.024[d]	0.25	0.015
	2009[e]			0.63	0.024[d]	0.15	0.007

* - gross vehicle weight (GVW)
a - 1997: manual transmission vehicles; 1998: automatic transmission vehicles
b - full implementation by the end of 2005
c - full phase-in by 2011
d - non-methane hydrocarbons
e - 2009.10 for new domestic models; 2010.09 for existing models & imports

Emission standards for new diesel fueled commercial vehicles are summarized in Table 1 for light vehicles (chassis dynamometer test) and in Table 2 for heavy vehicles (engine dynamometer test).

Light-duty trucks and buses are tested on the 10-15 mode cycle, which will be fully replaced by the JC08 mode test by 2011. The test procedure for heavy-duty engines is the JE05 mode cycle (hot start version). Before 2005, heavy-duty engines were tested over the 13-mode cycle and the 6-mode cycle. Vehicles and engines are tested using 50 ppm S fuel for the 2005 standards.

Table 2
Diesel Emission Standards for Heavy Commercial Vehicles
GVW > 3500 kg (> 2500 kg before 2005)

Date	Test	Unit	CO	HC	NO_x	PM
			mean (max)	mean (max)	mean (max)	mean (max)
1988/89	6 mode	ppm	790 (980)	510 (670)	DI: 400 (520) IDI: 260 (350)	
1994	13 mode	g/kWh	7.40 (9.20)	2.90 (3.80)	DI: 6.00 (7.80) IDI: 5.00 (6.80)	0.70 (0.96)
1997[a]			7.40 (9.20)	2.90 (3.80)	4.50 (5.80)	0.25 (0.49)
2003[b]			2.22	0.87	3.38	0.18
2005[c]	JE05		2.22	0.17[d]	2.0	0.027
2009			2.22	0.17[d]	0.7	0.01

a - 1997: GVW ≤ 3500 kg; 1998: 3500 < GVW ≤ 12000 kg; 1999: GVW > 12000 kg
b - 2003: GVW ≤ 12000 kg; 2004: GVW > 12000 kg
c - full implementation by the end of 2005
d - non-methane hydrocarbons

Emissions Standards: Japan
Off-Road Engines

Regulatory Background

After the reorganization of Japanese government in 2001, off-road engine emission standards became the responsibility of MOE and MLIT. The former MOT/MOC emission regulations were replaced by three groups of emission standards, applicable to the following categories of equipment:

i. *Special Motor Vehicles* — self-propelled nonroad vehicles and machinery that are registered for operation on public roads (fitted with license plates).

ii. *Nonroad Motor Vehicles* — self-propelled and non-registered nonroad vehicles and machinery.

iii. *Portable And Transportable Equipment: Recognition System* — recognition of low emission engines for designation of low emission construction machinery.

Special/Nonroad Motor Vehicles

These standards apply to nonroad vehicles rated between 19-560 kW with *(Special Motor Vehicles)* or without *(Nonroad Motor Vehicles)* licence plates. The emission limits for the two vehicle categories are the same, but they are introduced by separate regulatory acts. On June 28, 2005, the MOE promulgated a new set of standards for Special Vehicles, superseding former MOT standards. On March 28, 2006, the same standards were promulgated for Nonroad Vehicles, superseding former MOC standards.

The standards are summarized in Table 1 for compression ignition engines, and in Table 2 for spark ignited engines.

Table 1
Emission Standards for Diesel Special/Nonroad Vehicles, g/kWh

Power (P)	CO	HC	NO_x	PM	Smoke	Date	
						New Models	All Models†
kW	g/kWh				%		
19 ≤ P < 37	5.0	1.0	6.0	0.4	40	2007.10	2008.09
37 ≤ P < 56	5.0	0.7	4.0	0.3	35	2008.10	2009.09
56 ≤ P < 75	5.0	0.7	4.0	0.25	30	2008.10	2010.09
75 ≤ P < 130	5.0	0.4	3.6	0.2	25	2007.10	2008.09
130 ≤ P < 560	3.5	0.4	3.6	0.17	25	2006.10	2008.09

† Applies to continuously produced nonroad vehicles (but not special vehicles) and imported special/nonroad vehicles.

Table 2
Emission Standards for Spark Ignited Special/Nonroad Vehicles, g/kWh

Power (P)	7-mode			Idle		Date	
	CO	HC	NO_x	CO	HC	New Models	All Models†
kW	g/kWh			%	ppm		
19 ≤ P < 560	20.0	0.60	0.60	1	500	2007.10	2008.09

† Applies to continuously produced nonroad vehicles (but not special vehicles) and imported special/nonroad vehicles.

Emissions are measured according to JIS B 8001-1 (Japanese version of ISO 8178) 8-mode test for diesel, 7-mode test for SI. Smoke is measured according to JCMAS T-004.

These standards, although similar in stringency to the US Tier 3 (2006-2008) and the EU Stage III A (2005-2007), are not harmonized with US and EU regulations. The standards do not require the use of exhaust aftertreatment devices, such as diesel particulate filters. The MOE's Central Environmental

Council indicated it will consider adopting "aftertreatment-forcing" standards with implementation dates around 2010.

Portable/Transportable Equipment (Recognition System)

Under the recognition system regulations that became effective on March 17, 2006, manufacturers may apply for their engines to be recognized as a *low emission engine* for use in designated *low emission construction machinery*. The recognition system applies to portable and transportable (i.e., non-self-propelled) equipment, which is not emission regulated under the Special/Nonroad Motor Vehicle regulations.

The emission standards are listed in Table 3. Emissions are measured over the JIS B 8001-1 (ISO 8178) 8-mode test. For generator application, the rated speed is for 60 Hz and the intermediate speed is for 50 Hz.

Table 3
Emission Limits — Recognition System, g/kWh

Power (P)	CO	HC	NO_x	PM	Smoke
kW	g/kWh				%
8 ≤ P < 19	5.0	7.5*		0.4	40
19 ≤ P < 37	5.0	1.0	6.0	0.4	40
37 ≤ P < 56	5.0	0.7	4.0	0.3	35
56 ≤ P < 75	5.0	0.7	4.0	0.25	30
75 ≤ P < 130	5.0	0.4	3.6	0.2	25
130 ≤ P < 560	3.5	0.4	3.6	0.17	25
* NO_x + HC					

Emissions Standards: Japan
Fuel Economy

Heavy-Duty Vehicles: 2015 Targets

The fuel economy standards for heavy vehicles — effective from 2015 — apply to diesel fueled, type-approved commercial vehicles with GVW > 3.5 t, including trucks and buses designed to carry 11 or more passengers. The standards are also applicable to non-type-approved diesel vehicles that are equipped with CO or other emission control devices. Fuel economy from heavy vehicles fueled by gasoline, LPG or other alternative fuels is not regulated.

When the targets are fully met, the fleet average fuel economy is estimated at:

- For trucks: 7.09 km/L (369.6 g CO_2/km), a 12.2% increase over 2002 performance of 6.32 km/L (414.6 g CO_2/km),
- For buses: 6.30 km/L (416.0 g CO_2/km), a 12.1% increase over 2002 performance of 5.62 km/L (466.3 g CO_2/km).

The standards for heavy vehicles are summarized in the following tables.

Table 3.1
2015 Fuel Efficiency Targets for Heavy-Duty Transit Buses

Category	GVW, t	FE Target, km/L
1	6 < GVW ≤ 8	6.97
2	8 < GVW ≤ 10	6.30
3	10 < GVW ≤ 12	5.77
4	12 < GVW ≤ 14	5.14
5	14 < GVW	4.23

Table 3.2
2015 Fuel Efficiency Targets for Heavy-Duty General (Non-Transit) Buses

Category	GVW, t	FE Target, km/L
1	3.5 < GVW ≤ 6	9.04
2	6 < GVW ≤ 8	6.52
3	8 < GVW ≤ 10	6.37
4	10 < GVW ≤ 12	5.70
5	12 < GVW ≤ 14	5.21
6	14 < GVW ≤ 16	4.06
7	16 < GVW	3.57

Table 3.3
2015 Fuel Efficiency Targets for Heavy-Duty Trucks (Excluding Tractors)

Category	GVW, t	Max Load (L), t	FE Target, km/L
1	3.5 < GVW ≤ 7.5	L ≤ 1.5	10.83
2		1.5 < L ≤ 2	10.35
3		2 < L ≤ 3	9.51
4		3 < L	8.12
5	7.5 < GVW ≤ 8		7.24
6	8 < GVW ≤ 10		6.52
7	10 < GVW ≤ 12		6.00
8	12 < GVW ≤ 14		5.69
9	14 < GVW ≤ 16		4.97
10	16 < GVW ≤ 20		4.15
11	20 < GVW		4.04

Table 3.4
2015 Fuel Efficiency Targets for Heavy-Duty Tractors

Category	GVW, t	FE Target, km/L
1	GVW ≤ 20	3.09
2	GVW > 20	2.01

Testing. A computer simulation procedure has been developed that allows to calculate fuel efficiency (in km/L) of heavy-duty trucks and buses based on engine dynamometer testing. The engine testing is performed over the urban JE05 test and over an interurban transient test (speed: 80 km/h, load factor: 50%). A number of vehicle factors, such as vehicle mass, payload, tire size, gear ratios and efficiency, and others are accounted for in the calculation.

Background

Vehicle and engine emission standards are adopted at the federal level in China by the Ministry of Environmental Protection (MEP). In addition to National Standards, which are mandatory nationwide, Environmental Standards may apply to industries that have an impact on the quality of the environment, and Local Standards may be issued by local governments. The following naming conventions (prefixes) apply to the various types of regulations and standards:

- GB — mandatory national standards,
- GB/T — recommended national standards,
- HJ — environmental standards,
- HJ/T — recommended environmental standards,
- BJ (Beijing) and SH (Shanghai) are example local standards.

First emission regulations for motor vehicles became effective in the 1990s *[Regulation GB 14761]*. Chinese standards are based on European regulations, which are being adopted with a certain time delay.

Large metropolitan areas, including Beijing and Shanghai, have adopted more stringent regulations on an accelerated schedule, ahead of the rest of the country. Beijing implemented Euro 4 standards for light-duty vehicles in 2008 (the year of the Beijing Olympics) and plans to introduce Euro 5-based standards from 2012.

Heavy-Duty Truck and Bus Engines

Emission standards for new heavy-duty truck and bus engines are based on the European standards. Regulation GB 17691-2005 specifies the emission limits for China III-V stages, which are based on Euro III-V, respectively. The emission limits are shown in Table 1.

The following provisions apply to emissions of ammonia and nitrogen dioxide:

- NO_2 requirements: OEMs are required to report tailpipe NO_2 concentration and NO_2 increase level if an oxidation catalyst-based aftertreatment system is used, such as DOC, POC, DPF or NAC.
- NH_3 slip limit: No limit for China IV. For China V, NH_3 slip limit is 25 ppm (peak) and 10 ppm (cycle average).

Implementation dates for the standards are listed in Table 2. The dates generally refer to new type approvals — first registration of existing vehicle models is typically allowed for one more year.

Emission durability requirements, including the engine useful life and the minimum aftertreatment testing periods, are shown in Table 3. The aftertreatment periods according to HJ 438-2008 are mandatory for type approval and production conformity, while GB 20890-2007 provides a guideline to conduct aftertreatment durability testing during product development.

The GB 20890-2007 standard recommends that aftertreatment testing be conducted on-vehicle, over the China Heavy-Duty Durability Cycle — Vehicle (C-HDD-V). Alternatively,

Table 1
Emission Standards for Heavy-Duty Engines

Standard	Test Cycle	CO	HC	NMHC	NO_x	PM	Smoke
		g/kWh					1/m
China III	ESC + ELR	2.1	0.66	-	5.0	0.10/0.13†	0.8
	ETC	5.45	-	0.78	5.0	0.16/0.21†	-
China IV	ESC + ELR	1.5	0.46	-	3.5	0.02	0.5
	ETC	4.0	-	0.55	3.5	0.03	-
China V	ESC + ELR	1.5	0.46	-	2.0	0.02	0.5
	ETC	4.0	-	0.55	2.0	0.03	-

† For engines with a per cylinder displacement of < 0.75 L and rated speed > 3000 rpm

At the China I/II stage (not shown in the table), the test was ECE R-49 or the Chinese 9-mode.

Table 2
Emission Standards Implementation Dates

Standard Beijing		Actual Date: Shanghai	Guangzhou	Nationwide		Initially Scheduled
China I					2000.09	
China II					2003.09	
China III	Gasoline	2010.07	2010.08	2009.07	2007.07	2007.07
	Diesel	2006.01	2007.01	2007.07		2007.01
China IV	Gasoline	2011.01				2010.01
	Diesel	2011.01	2009.11	2010.08	2013.07	2010.01
China V	Gasoline	2012.06				
	Diesel	2012.06				

Table 3
Emission Durability Requirements

Category	Useful Life	Aftertreatment Testing: GB 20890-2007	HJ 438-2008
M1 (GVW > 3.5 t) M2	100,000 km/5 yrs	50,000 km	100,000 km
M3 (GVW ≤ 7.5 t) N2 and N3 (GVW ≤ 16 t)	200,000 km/6 yrs	60,000 km	125,000 km
M3 (GVW > 7.5 t) N3 (GVW > 16 t)	500,000 km/7 yrs	80,000 km	167,000 km

an engine based durability test can be conducted over the China Heavy-Duty Durability Cycle — Engine (C-HDD-E).

Nonroad Engines

Emission standards for mobile nonroad engines were adopted in 2007 *[Regulation GB 20891-2007]*. The requirements, outlined in Table 4, are based on the European Stage I/II emission standards for mobile nonroad engines. However, the Chinese regulation also covers small diesel engines, which were not subject to the European standards. Emission limits for the smallest engines are consistent with the US Tier 1/2 nonroad standards.

The compliance dates are:

- Stage I standards: 2007.10
- Stage II standards: 2009.10

Table 4
Emission Standards for Nonroad Diesel Engines, g/kWh

Max Power (P), kW	CO	HC	NO_x	HC+NO_x	PM
Stage I†					
130 ≤ P ≤ 560	5.0	1.3	9.2	-	0.54
75 ≤ P < 130	5.0	1.3	9.2	-	0.7
37 ≤ P < 75	6.5	1.3	9.2	-	0.85
18 ≤ P < 37	8.4	2.1	10.8	-	1.0
8 ≤ P < 18	8.4	-	-	12.9	-
0 < P < 8	12.3	-	-	18.4	-
Stage II					
130 ≤ P ≤ 560	3.5	1.0	6.0	-	0.2
75 ≤ P < 130	5.0	1.0	6.0	-	0.3
37 ≤ P < 75	5.0	1.3	7.0	-	0.4
18 ≤ P < 37	5.5	1.5	8.0	-	0.8
8 ≤ P < 18	6.6	-	-	9.5	0.8
0 < P < 8	8.0	-	-	10.5	1.0

† Stage I limits shall be achieved before any exhaust aftertreatment device.

Emissions are measured over a steady-state test cycle that is equivalent to the ISO 8178 C1, 8-mode test. Other ISO 8178 test cycles can be used for selected applications.

Emissions Standards: India
On-Road Vehicles And Engines

Background

The first Indian emission regulations were idle emission limits which became effective in 1989. These idle emission regulations were soon replaced by mass emission limits for both gasoline (1991) and diesel (1992) vehicles, which were gradually tightened during the 1990's. Since the year 2000, India started adopting European emission and fuel regulations for four-wheeled light-duty and for heavy-duty vehicles. Indian own emission regulations still apply to two- and three-wheeled vehicles.

On October 6, 2003, the National Auto Fuel Policy has been announced, which envisages a phased program for introducing Euro 2 — 4 emission and fuel regulations by 2010. The implementation schedule of EU emission standards in India is summarized in Table 1.

Table 1
Indian Emission Standards (4-Wheel Vehicles)

Standard	Reference	Date	Region
India 2000	Euro 1	2000	Nationwide
Bharat Stage II	Euro 2	2001	NCR*, Mumbai, Kolkata, Chennai
		2003.04	NCR*, 11 Cities†
		2005.04	Nationwide
Bharat Stage III	Euro 3	2005.04	NCR*, 11 Cities†
		2010.04	Nationwide
Bharat Stage IV	Euro 4	2010.04	NCR*, 11 Cities†

* National Capital Region (Delhi)
† Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Secunderabad, Ahmedabad, Pune, Surat, Kanpur and Agra

The above standards apply to all new 4-wheel vehicles sold and registered in the respective regions. In addition, the National Auto Fuel Policy introduces certain emission requirements for interstate buses with routes originating or terminating in Delhi or the other 10 cities.

Light Duty Vehicles

Emission standards for light-duty vehicles (GVW ≤ 3,500 kg)

Table 2
Emission Standards for Light-Duty Vehicles, g/km

Year	Reference	CO	HC	HC+NO_x	NO_x	PM
Diesel						
1992	-	17.3-32.6	2.7-3.7	-	-	-
1996	-	5.0-9.0	-	2.0-4.0	-	-
2000	Euro 1	2.72-6.90	-	0.97-1.70	-	0.14-0.25
2005†	Euro 2	1.0-1.5	-	0.7-1.2	-	0.08-0.17
2010†	Euro 3	0.64 0.80 0.95	-	0.56 0.72 0.86	0.50 0.65 0.78	0.05 0.07 0.10
2010‡	Euro 4	0.50 0.63 0.74	-	0.30 0.39 0.46	0.25 0.33 0.39	0.025 0.04 0.06
Gasoline						
1991	-	14.3-27.1	2.0-2.9	-	-	-
1996	-	8.68-12.4	-	3.00-4.36	-	-
1998*	-	4.34-6.20	-	1.50-2.18	-	-
2000	Euro 1	2.72-6.90	-	0.97-1.70	-	-
2005†	Euro 2	2.2-5.0	-	0.5-0.7	-	-
2010†	Euro 3	2.3 4.17 5.22	0.20 0.25 0.29	-	0.15 0.18 0.21	-
2010‡	Euro 4	1.0 1.81 2.27	0.1 0.13 0.16	-	0.08 0.10 0.11	-

* for catalytic converter fitted vehicles
† earlier introduction in selected regions, see Table 1
‡ only in selected regions, see Table 1

Table 3
Alternative Emission Standards for Light-Duty Diesel Engines, g/kWh

Year	Reference	CO	HC	NO_x	PM
1992	-	14.0	3.5	18.0	-
1996	-	11.20	2.40	14.4	-
2000	Euro I	4.5	1.1	8.0	0.36*
2005†	Euro II	4.0	1.1	7.0	0.15

* 0.612 for engines below 85 kW
† earlier introduction in selected regions, see Table 1

are summarized in Table 2. Ranges of emission limits refer to different categories and classes of vehicles; compare the EU light-duty vehicle emission standards page for details on the Euro 1 and later standards. The lowest limit in each range applies to passenger cars (GVW ≤ 2,500 kg; up to 6 seats). When three limits are listed, they refer to vehicles category M & N1 Class I, N1 Class II, and N1 Class III, respectively.

The test cycle has been the NEDC for low-powered vehicles (max. speed limited to 90 km/h). Before 2000, emissions were measured over an Indian test cycle.

Gasoline vehicles must also meet an evaporative (SHED) limit of 2 g/test (effective 2000).

Through the BS II (Euro II) stage, engines for use in light-duty vehicles could be alternatively emission tested using an engine dynamometer. The respective emission standards are listed in Table 3.

OBD Requirements. OBD I is required from 1 April 2010 (except LPG or CNG-fuelled vehicles and those >3500 kg GVW). OBD II is required from 1 April 2013 for all categories.

Truck and Bus Engines

Emission standards for new heavy-duty engines — applicable to vehicles of GVW > 3,500 kg — are listed in Table 4.

Table 4
Emission Standards for Diesel Truck and Bus Engines, g/kWh

Year	Reference	Test	CO	HC	NO_x	PM
1992	-	ECE R49	17.3-32.6	2.7-3.7	-	-
1996	-	ECE R49	11.20	2.40	14.4	-
2000	Euro I	ECE R49	4.5	1.1	8.0	0.36*
2005†	Euro II	ECE R49	4.0	1.1	7.0	0.15
2010†	Euro III	ESC	2.1	0.66	5.0	0.10
		ETC	5.45	0.78	5.0	0.16
2010‡	Euro IV	ESC	1.5	0.46	3.5	0.02
		ETC	4.0	0.55	3.5	0.03

* 0.612 for engines below 85 kW
† earlier introduction in selected regions, see Table 1
‡ only in selected regions, see Table 1

Construction Machinery

Emission standards for diesel construction machinery were adopted on 21 September 2006. The standards are structured into two tiers:

- Bharat (CEV) Stage II — These standards are based on the EU Stage I requirements, but also cover smaller engines that were not regulated under the EU Stage I.
- Bharat (CEV) Stage III — These standards are based on US Tier 2/3 requirements.

The standards are summarized in Table 1:

Table 1
Bharat (CEV) Emission Standards for Diesel Construction Machinery

Engine Power	Date	CO	HC	HC+NO_x	NO_x	PM
kW		g/kWh				
Bharat (CEV) Stage II						
P < 8	2008.10	8.0	1.3	-	9.2	1.00
8 ≤ P < 19	2008.10	6.6	1.3	-	9.2	0.85
19 ≤ P < 37	2007.10	6.5	1.3	-	9.2	0.85
37 ≤ P < 75	2007.10	6.5	1.3	-	9.2	0.85
75 ≤ P < 130	2007.10	5.0	1.3	-	9.2	0.70
130 ≤ P < 560	2007.10	5.0	1.3	-	9.2	0.54
Bharat (CEV) Stage III						
P < 8	2011.04	8.0	-	7.5	-	0.80
8 ≤ P < 19	2011.04	6.6	-	7.5	-	0.80
19 ≤ P < 37	2011.04	5.5	-	7.5	-	0.60
37 ≤ P < 75	2011.04	5.0	-	4.7	-	0.40
75 ≤ P < 130	2011.04	5.0	-	4.0	-	0.30
130 ≤ P < 560	2011.04	3.5	-	4.0	-	0.20

Table 2
Bharat (CEV) Stage III Useful Life Periods

Power Rating		Useful Life Period
		hours
< 19 kW		3000
19-37 kW	constant speed	3000
	variable speed	5000
> 37 kW		8000

The limit values apply for both type approval (TA) and conformity of production (COP) testing. Testing is performed on an engine dynamometer over the ISO 8178 C1 (8-mode) and D2 (5-mode) test cycles.

The Bharat Stage III standards must be met over the useful life periods shown in Table 2. Alternatively, manufacturers may use fixed emission deterioration factors of 1.1 for CO, 1.05 for HC, 1.05 for NO_x, and 1.1 for PM.

Table 3
Bharat (Trem) Emission Standards for Diesel Agricultural Tractors

Engine Power	Date	CO	HC	HC+NO_x	NO_x	PM
kW		g/kWh				
Bharat (Trem) Stage I						
All	1999.10	14.0	3.5	-	18.0	-
Bharat (Trem) Stage II						
All	2003.06	9.0	-	15.0	-	1.00
Bharat (Trem) Stage III						
All	2005.10	5.5	-	9.5	-	0.80
Bharat (Trem) Stage III A						
P < 8	2010.04	5.5	-	8.5	-	0.80
8 ≤ P < 19	2010.04	5.5	-	8.5	-	0.80
19 ≤ P < 37	2010.04	5.5	-	7.5	-	0.60
37 ≤ P < 75	2011.04	5.0	-	4.7	-	0.40
75 ≤ P < 130	2011.04	5.0	-	4.0	-	0.30
130 ≤ P < 560	2011.04	3.5	-	4.0	-	0.20

Agricultural Tractors

Emission standards for diesel agricultural tractors are summarized in Table 3.

Emissions are tested over the ISO 8178 C1 (8-mode) cycle. For Bharat (Trem) Stage III A, the useful life periods and deterioration factors are the same as for Bharat (CEV) Stage III, Table 2.

Emissions Standards: India
Generator Sets

Table 1
Emission Standards for Diesel Engines ≤ 800 kW for Generator Sets

Engine Power (P)	Date	CO	HC	NO_x	PM	Smoke
		g/kWh				1/m
P ≤ 19 kW	2004.01	5.0	1.3	9.2	0.6	0.7
	2005.07	3.5	1.3	9.2	0.3	0.7
19 kW < P ≤ 50 kW	2004.01	5.0	1.3	9.2	0.5	0.7
	2004.07	3.5	1.3	9.2	0.3	0.7
50 kW < P ≤ 176 kW	2004.01	3.5	1.3	9.2	0.3	0.7
176 kW < P ≤ 800 kW	2004.11	3.5	1.3	9.2	0.3	0.7

Emissions from new diesel engines used in generator sets have been regulated by the Ministry of Environment and Forests, Government of India *[GSR 371(E), 17.05.2002]*. The regulations impose type approval certification, production conformity testing and labeling requirements. Certification agencies include: (1) Automotive Research Association of India, (2) Vehicle Research and Development Establishment, and (3) International Centre for Automotive Technology *[GSR 280(E), 11.04.2008]*. The emission standards are listed below.

Table 2
Emission Limits for Diesel Engines > 800 kW for Generator Sets

Date	CO	NMHC	NO_x	PM
	mg/Nm^3	mg/Nm^3	ppm(v)	mg/Nm^3
Until 2003.06	150	150	1100	75
2003.07 - 2005.06	150	100	970	75
2005.07	150	100	710	75

Engines are tested over the 5-mode ISO 8178 D2 test cycle. Smoke opacity is measured at full load. Concentrations are corrected to dry exhaust conditions with 15% residual O_2.

Emissions Standards: Korea
On-Road Vehicles And Engines

Light-Duty Vehicles

Korean diesel emission standards for passenger cars (<8 seats, GVW<2,500 kg) are listed in Table 1. Emission standards for light-duty diesel trucks (GVW<3,000 kg) are listed in Table 2.

Table 1
Emission Standards for Diesel Passenger Cars

Date	CO	HC	NMHC	NO_x	PM	Smoke
-	g/km					%
1993.1.1	2.11	0.25	-	0.62	0.12	
1996.1.1	2.11	0.25	-	0.62	0.08	
1998.1.1	1.50	0.25	-	0.62	0.08	
2000.1.1	1.20	0.25	-	0.62	0.05	20%
2001.1.1	0.5	-	0.01	0.02	0.01	20%
2002.7.1	0.5	-	0.01	0.02	0.01	15%

Emissions are tested over the US FTP-75 cycle and expressed in g/km.

The Korean government has proposed that Euro 4 emission standards will apply to light-duty diesel vehicles effective January 2006 (and California ULEV standards for gasoline vehicles).

Table 2
Emission Standards for Light-Duty Diesel Trucks

Date	CO	HC	NO_x	PM
-	g/km			
1993-1997				
1993.1.1	980†	670†	350† IDI 750† DI	-
1996.1.1	6.21	0.50	1.43	0.31
1998 and later, LW<1,700 kg				
1998.1.1	2.11	0.25	1.40	0.14
2000.1.1	2.11	0.25	1.02	0.11
2004.1.1	1.27	0.21	0.64	0.06
1998 and later, LW>1,700 kg				
1998.1.1	2.11	0.50	1.40	0.25
2000.1.1	2.11	0.50	1.06	0.14
2004.1.1	1.52	0.33	0.71	0.08

LW (loaded weight) = curb weight + 130 kg
† JP 6-mode test, limits expressed in ppm

Heavy-Duty Vehicles

Korean emission standards for heavy-duty diesel trucks (GVW>3,000 kg) are listed in Table 3. Some of the truck engine categories have additional smoke opacity requirements which are not listed in the table.

Since 1996, emissions are tested over the Japanese diesel 13-mode cycle and expressed in g/kWh. The 2003 emission limits are aligned with Euro III requirements.

Table 3
Emission Standards for Heavy-Duty Diesel Engines

Date	CO	HC	NO_x	PM
-	g/kWh			
1993.1.1	980†	670†	350† IDI 750† DI	-
1996.1.1	4.90	1.20	11.0	0.90
1998.1.1	4.90	1.20	6.0 (9.0)*	0.25 (0.50)*
2000.1.1	4.90	1.20	6.0	0.25 (0.10)*
2002.1.1	4.90	1.20	6.0	0.15 (0.10)*
2003.1.1	2.1	0.66	5.0	0.10

* applies to buses
† JP 6-mode test, limits expressed in ppm

Emissions Standards: Korea
Nonroad Engines

Korea has proposed emission standards for mobile nonroad diesel engines used in construction and industrial equipment. The standards would apply to engines between 18 - 560 kW rated power, in such applications as excavators (>1 t), bulldozers, loaders (>2 t), cranes, graders, rollers, and forklift trucks.

The standards would be implemented in two Tier schedules, as shown in Table 1. The Korean Tier 2 standards are equivalent to the U.S. Tier 2. Emissions are measured over the ISO 8178 C1 test and expressed in g/kWh. There are no smoke opacity requirements.

Table 1
Proposed Emission Standards for Nonroad Engines

Power	CO	HC	NO_x+HC	NOx	PM
kW	g/kWh				
Tier 1: 2004.1.1					
18 - 37	5.5	-	9.5	-	0.8
37 - 75	5.5	1.3	-	9.2	0.6
75 - 130	5.0	1.3	-	9.2	0.6
130 - 225	5.0	1.3	-	9.2	0.54
225 - 560	5.0	1.3	-	9.2	0.54
Tier 2: 2005.1.1					
18 - 37	5.5	-	7.5	-	0.6
37 - 75	5.0	-	7.5	-	0.4
75 - 130	5.0	-	6.6	-	0.3
130 - 225	3.5	-	6.6	-	0.2
225 - 560	3.5	-	6.4	-	0.2

Diesel fuel specifications are: density 815 - 855 kg/m^3, sulfur < 430 ppm.

Engines (engine families) are to be certified by the Korean Ministry of Environment or the National Institute of Environmental Research.

On-Road Vehicles And Engines

Background

Australian emissions standards are based on European regulations for light-duty and heavy-duty (heavy goods) vehicles, with acceptance of selected US and Japanese standards. The long term policy is to fully harmonize Australian regulations with UN ECE standards. The development of emissions standards for highway vehicles and engines is coordinated by the National Transport Commission (NTC) and the regulations — Australian Design Rules (ADR) — are administered by the Department of Infrastructure and Transport.

The emissions standards apply to new vehicles including petrol (gasoline) and diesel cars, light omnibuses, heavy omnibuses, light goods vehicles, medium goods vehicles and heavy goods vehicles, as well as to forward control passenger vehicles and larger motor tricycles. They also cover off-road passenger vehicles (but not off-road engines, such as those used in construction or agricultural machinery).

The evolution of vehicle emissions standards in Australia occurred through a number of regulatory actions. Some of the important steps can be summarized as follows:

- Emission standards for petrol engined light vehicles commenced in the early 1970s.
- A smoke emissions requirement (ADR30/00) was introduced in 1976 for vehicles with 4 or more wheels powered by a diesel engine. The alternative smoke standards were US EPA '74 or later or British standards "Performance of Diesel Engines for Road Vehicles" BS AU 141a:1971 or ECE R 24/00, 24/01, 24/02 or 24/03 "Diesel and Pollutants" or, in the case of an engine alone, ECE R 24/03.
- The first emissions standards (apart from smoke standards) for heavy diesel fueled vehicles became effective in 1995 for all new models and in 1996 for all existing models. These emissions standards were introduced via ADR70/00 (adopting ECE R49, US & Japanese HDV standards). The requirements of the 1995/96 standards were:
    - Required: Euro 1 for both light-duty and heavy-duty vehicles. Euro 2 and 3 were also accepted though not included in the regulation.
    - Acceptable alternatives: US EPA '91 or '94 (EPA '98 was also accepted though not included in the regulation); 1993 Japanese exhaust emissions standards for "light duty and medium duty vehicles" and 1994 Japanese exhaust emissions standards for "passenger cars and heavy duty vehicles".
- A second round of more stringent emissions standards applied from 2002/2003 model year (for new/existing models). The standards — initially equivalent to Euro 2/3 — have been gradually tightened to adopt Euro 4 for light-duty cars and trucks (diesel and petrol), and Euro 5 for heavy-duty diesel engines.
- A third round of emissions regulations, adopted in 2011, mandates Euro 5/6 emissions standards for light-duty vehicles with an implementation schedule from 2013 to 2018.

Emissions Standards: 2002/03 and Later

The emissions standards were introduced via a series of new ADRs, which apply to vehicles depending on their gross vehicle mass (GVM):

- For light-duty vehicles at or below 3.5 t GVM:
    - Euro 2/4 stage: ADR79/00, ADR79/01, and ADR79/02 (replacing ADR37/01)
    - Euro 5/6 stage: ADR79/03, ADR79/04, and ADR79/05
- For heavy-duty vehicles above 3.5 t GVM: ADR80/00, ADR80/01, ADR80/02, and ADR80/03 (replacing ADR70/00)

The above ADRs apply to new vehicles fueled with petrol, diesel, as well as with LPG or natural gas. The requirements and the implementation schedules are summarized in Table 1 (the requirements and dates for heavy LPG and NG vehicles are the same as for diesel).

The two year date combinations shown in the table refer to the dates applicable to new model vehicles and all model vehicles, respectively. For example, in the case of 02/03, this means that from January 1, 2002 any new model first produced with a date of manufacture after January 1, 2002 must comply with the ADR, and from January 1, 2003 all new vehicles (regardless of the first production date for that particular model) must comply.

Notes to Table 1

1. The introduction of Euro 2 standards for light-duty petrol and light-duty diesel vehicles is via ADR79/00, which adopts the technical requirements of ECE R83/04.

2. The introduction of Euro 3 standards for light-duty petrol vehicles, and Euro 4 standards for light-duty diesel vehicles, is via ADR79/01, which adopts the technical requirements of ECE Regulation 83/05. R83/05 embodies the Euro 3 and Euro 4 requirements for light-duty petrol and diesel vehicles, however the ADR only mandates the Euro 3 (pre 2005) provisions of R83/05 for petrol vehicles, but allows petrol vehicles optional compliance with Euro 4 standards.

3. The introduction of Euro 4 standards for light-duty petrol

vehicles is via ADR79/02, which adopts the technical requirements of ECE R83/05.

4. The introduction of Euro 3 and Euro 4 standards for medium- and heavy-duty diesel vehicles is via ADR80/00 and ADR80/01, respectively, which adopt the technical requirements of European Directive 99/96/EC amending Directive 88/77/EEC. ADR80/01 has been replaced by ADR80/02 effective 2007/8.

5. The introduction of Euro 4 and Euro 5 standards for medium- and heavy-duty diesel vehicles is via ADR80/02 and ADR80/03, respectively, which adopt the technical requirements of Directive 2005/55/EC as amended by 2005/78/EC and 2006/51/EC.

6. The 'core' Euro 5 (ADR79/03) adopts the technical requirements of ECE R83/06, except that it does not require the new, PMP-based testing methods for PM mass (allowing the old test method with the 0.005 g/km PM limit to be used as an alternative) and has no PN limit. Some other requirements are also relaxed, including the OBD threshold. ADR79/04 applies the full requirements of ECE R83/06 from 1 November 2016.

Other Provisions

Smoke Limits. A smoke emissions ADR30/01 also applies to all categories of diesel vehicles. The smoke standard, which applies from 2002/3, adopts UN ECE R24/03 and allows the US 94 smoke standards as an alternative. This new ADR replaces ADR30/00.

OBD. ADR79/03-05 introduces European OBD requirements for light-duty vehicles. At the 'core' Euro 5 stage (ADR79/03) a relaxed OBD threshold limit for PM mass of 80 mg/km is accepted for M and N category vehicles of reference mass above 1760 kg.

ADR80/02 requires heavy-duty vehicles to have OBD systems meeting the Euro 4 (or Japanese) requirements to

Table 1
Vehicle Emission Standards: 2002/03 and Later

ADR Categories			ECE Cat	ADR	02/03	03/04	05/06	06/07	07/08	08/10[a]	10/11	10/11	13/16[b]	17/18[c]
Descr	GVM†	Cat‡			Diesel	Petrol	Petrol	Diesel	Diesel	Petrol	Petrol	Diesel	All	All
Passenger Vehicles														
	≤ 3.5t	MA, MB, MC	M1	ADR 79/..	Euro 2	Euro 2	Euro 3	Euro 4		Euro 4			Euro 5[d]	Euro 6
	> 3.5t			ADR 80/..	Euro 3	US96	US98		Euro 4		Euro 4			
Buses														
Light	≤ 3.5t	MD	M2	ADR 79/..	Euro 2	Euro 2	Euro 3	Euro 4		Euro 4			Euro 5[d]	Euro 6
	3.5 ≤ 5t			ADR 80/..	Euro 3	US96	US98		Euro 4 or US04, JE05		Euro 4 or US08	Euro 5 or US07, JE05		
Heavy	> 5t	ME	M3	ADR 80/..	Euro 3 or US98[e]	US96	US98		Euro 4 or US04, JE05		Euro 4 or US08	Euro 5 or US07, JE05		
Goods Vehicles (Trucks)														
Light	≤ 3.5t	NA	N1	ADR 79/..	Euro 2	Euro 2	Euro 3	Euro 4		Euro 4			Euro 5[d]	Euro 6
Medium	3.5 ≤ 12t	NB	N2	ADR 80/..	Euro 3 or US98[e]	US96	US98		Euro 4 or US04, JE05		Euro 4 or US08	Euro 5 or US07, JE05		
Heavy	> 12t	NC	N3	ADR 80/..	Euro 3 or US98[e]	US96	US98		Euro 4 or US04, JE05		Euro 4 or US08	Euro 5 or US07, JE05		

† Gross vehicle mass
‡ Vehicle categories: MA - passenger cars; MB - forward control vehicles, MC - passenger off-road vehicles
a - 1 July 2008/1 July 2010 for new/existing models
b - 1 November 2013/1 November 2016 for new/existing models
c - 1 July 2017/1 July 2018 for new/existing models
d - 'Core' Euro 5 applicable to new models from 1 November 2013, full Euro 5 applicable from 1 November 2016 (see notes below)
e - US EPA model year 2000 or later certificate or equivalent testing required (to ensure that no emission "defeat devices" are used)

warn against "functional failures" (such as an empty urea tank in engines with SCR). ADR80/03 requires vehicles to have OBD systems meeting the Euro 5 requirements to directly monitor emissions levels against set OBD thresholds.

Diesel Fuel. The new emissions requirements were synchronized with new diesel fuel specifications of reduced sulfur content, as follows:

- 500 ppm sulfur effective December 31, 2002
- 50 ppm sulfur effective January 1, 2006
- 10 ppm sulfur effective January 1, 2009

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Emissions Standards: Argentina
On-Road Vehicles And Engines

Trucks and Buses

Emission standards for new diesel fueled trucks and buses in Argentina are summarized in Table 1 *[Decree 779/95; Resolution 731/2005]*. Through the 2000 stage, the standards were also applicable to light commercial vehicles (LCV, engine certification), as indicated. The standards are based on European heavy-duty engine emission regulations.

The limits for 2006 and later heavy-duty engines established by Resolution 731/2005 are those of European Directive 1999/96/CE Stage A and B1 as opposed to limits that are numerically equal.

Table 1
Emission Standards for Diesel Trucks and Buses

Year	Reference Standard	CO	HC	NO_x	PM	Comments
		g/kWh				
1994	Euro 0	11.2	2.45	14.4	-	Urban buses
1995	Euro I*	4.9	1.23	9.0	-	Urban buses
1996	Euro I*	4.9	1.23	9.0	0.4[a]	LCV & Trucks
1998	Euro II	4.0	1.1	7.0	0.4[a]	Urban buses
2000	Euro II	4.0	1.1	7.0	0.15[a]	LCV & Trucks
2006[b]	Euro III					
2009[c]	Euro IV					

* production conformity limit
a - multiply by a factor of 1.7 for engines below 85 kW
b - New models; 2007 for all models
c - New models; 2011 for all models

Emissions Standards: Brazil
On-Road Vehicles And Engines

Background

Brazilian emissions standards for on-road vehicles and engines are adopted by the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renovaveis (IBAMA), an agency within the Ministry of Environment (Ministério do Meio Ambiente). The numerical emission limits and certification test cycles are based on European Union regulations. Important regulatory steps include:

- First set of vehicle emission regulations, adopted in 1993 [Conama 8/93], based on Euro 0/2 standards.
- Second set of emission standards, adopted in 2002 with implementation dates over 2006-2009 *[Conama 315/2002]*. The light-duty vehicle PROCONVE L4/L5 standards were based on Euro 3/4, while the heavy-duty PROCONVE P5/P6 were based on Euro III/IV standards.
- OBD requirements for domestically produced and imported Otto cycle light commercial vehicles, adopted in 2004 *[Conama 354/2004]*.
- PROCONVE P7 standards for heavy-duty engines, adoped in 2008 with implementation in 2012 *[Conama 403/2008]*, based on Euro V standards.
- PROCONVE L6 standards for light-duty vehicles, adoped in 2009 with implementation dates over 2013-2015 *[Conama 415/2008]*, based on Euro 5 standards.

Diesel engines have been used in Brazil in heavy-duty vehicles, such as trucks and buses, as well as in light-duty commercial vehicles, but are not allowed in passenger cars. For this reason, the first set of emission regulations did not include standards for diesel cars. Such standards have been included in the newer legislation (PROCONVE 4/5), in part because Brazilian standards are used as a base by neighboring South American countries, where diesels are used in passenger cars.

Light-Duty Vehicles

More stringent standards for passenger cars and light commercial vehicles became effective in 2007 (including the first standards for diesel cars). Details on these standards are shown in Table 1.1 and Table 1.2. Light vehicles are tested over a chassis dynamometer cycle (test standard NBR6601) which is based on the FTP-75 test.

It should be noted that the PROCONVE regulations tend to be more relaxed than the corresponding EU standards. For instance, the PROCONVE L6 — while based on Euro 5 — does not include the particulate filter-forcing PM mass or number emission standards.

The regulations also set an evaporative emissions limit of 2 g/test for Otto cycle engines, except those fueled by natural gas.

Table 1.1
Emission Standards For Passenger Vehicles
(FTP-75; Durability: 80,000 km/5 years)

Tier	Date	Idle CO	CO	THC	NMHC	NO_x	HCO	PM
		% vol	g/km					
PROCONVE L4	1.1.2007[1,2]	0.50	2.0	0.30	0.16	0.25[3]/0.60[4]	0.03	0.05
PROCONVE L5	1.1.2009	0.50	2.0	0.30	0.05	0.12[3]/0.25[4]	0.02	0.05
PROCONVE L6	1.1.2013[5]	0.20	1.3	0.30	0.05	0.08	0.02	0.025

Idle CO limits apply to Otto cycle engines only
THC limits apply to natural gas vehicles only
HCO limits apply to Otto cycle engines only; Natural gas vehicles exempted
PM limits apply to Diesel cycle engines only
(1) 1.1.2005: at least 40% of annual production (passenger vehicles + light commercial vehicles)
(2) 1.1.2006: at least 70% of annual production (passenger vehicles + light commercial vehicles)
(3) Otto cycle engines
(4) Diesel cycle engines
(5) For all diesel vehicles. Otto cycle 1.1.2014/1.1.2015 for new models/all registrations, respectively.

Table 1.2
Emission Standards For Light Commercial Vehicles
(FTP-75; Durability: 80,000 km/5 years)

Category*	Tier	Date	Idle CO	CO	THC	NMHC	NO_x	HCO	PM
			% vol	g/km					
≤1700 kg	PROCONVE L4	1.1.2007[1,2]	0.50	2.0	0.30	0.16	0.25[3]/0.60[4]	0.03	0.08
	PROCONVE L5	1.1.2009	0.50	2.0	0.30	0.05	0.12[3]/0.25[4]	0.02	0.05
	PROCONVE L6	1.1.2013[5]	0.20	1.3	0.30	0.05	0.08	0.02	0.03
>1700 kg	PROCONVE L4	1.1.2007[1,2]	0.50	2.7	0.50	0.20	0.43[3]/1.00[4]	0.06	0.10
	PROCONVE L5	1.1.2009	0.50	2.7	0.50	0.06	0.25[3]/0.43[4]	0.04	0.06
	PROCONVE L6	1.1.2013[5]	0.20	2.0	0.50	0.06	0.25[3]/0.35[4]	0.03	0.04

Idle CO limits apply to Otto cycle engines only
THC limits apply to natural gas vehicles only
HCO limits apply to Otto cycle engines only; Natural gas vehicles exempted
PM limits apply to Diesel cycle engines only
* Light Commercial Diesel Vehicles >2000 kg max. total mass are allowed to be homologated as HD, Table 2.2
(1) 1.1.2005: at least 40% of annual production (passenger vehicles + light commercial vehicles)
(2) 1.1.2006: at least 70% of annual production (passenger vehicles + light commercial vehicles)
(3) Otto cycle engines
(4) Diesel cycle engines
(5) For all diesel vehicles. Otto cycle 1.1.2014/1.1.2015 for new models/all registrations, respectively.

Trucks And Buses

Model Year 1993-2005. Emission standards for new MY 1993-2005 diesel fueled trucks and buses are summarized in Table 2.1. The same standards also applied to light-duty trucks. All truck and bus engines, including those used in light trucks, were certified on an engine dynamometer (test cycle ECE R-49).

In addition to the above standards, new engines have to meet the following free acceleration smoke limits (effective March 94):

- 0.83/m (30 HSU) for naturally aspirated engines
- 1.19/m (40 HSU) for turbocharged engines

Table 2.1
Emission Standards for Diesel-Fueled Trucks and Buses

Year	Category	Reference Standard	CO	HC	NO_x	PM
			g/kWh			
1993	All	Euro 0	11.2	2.45	14.4	-
1994	Urban buses	Euro 1*	4.9	1.23	9.0	-
1996	All	Euro 1*	4.9	1.23	9.0	0.4[a]
1998	Urban buses	Euro 2	4.0	1.1	7.0	0.15[b]
2000	All	Euro 2	4.0	1.1	7.0	0.15[b]

* - production conformity limit
a - multiply by a factor of 1.7 for engines below 85 kW
b - 0.25 g/kWh for engines up to 0.7 liter, rated speed above 3000 rpm

Model Year 2006 and Later. More stringent standards applicable to heavy-duty engines effective 2006 are summarized in Table 2.2. Diesel engines are tested over both the ESC and ETC tests, while gas engines are tested over the ETC test only (see also EU regulations).

Table 2.2
Emission Standards for HD Diesel And Gas Engines
(Durability: 160,000 km/5 years)

Tier	Date	Test	CO	THC	NMHC	NO_x	PM†	Smoke
			g/kWh					m^{-1}
PROCONVE P5	1.1.2006[1,2,3]	ESC/ELR	2.1	0.66	-	5.0	0.10 or 0.13[5]	0.8
		ETC[4]	5.45	-	0.78	5.0	0.16 or 0.21[5]	-
PROCONVE P6	1.1.2009[6]	ESC/ELR	1.5	0.46	-	3.5	0.02	0.5
		ETC	4.0	-	0.55	3.5	0.03	-
PROCONVE P7	1.1.2012	ESC/ELR	1.5	0.46	-	2.0	0.02	0.5
		ETC	4.0	-	0.55	2.0	0.03	-

† Applicable to diesel engines only
(1) 1.1.2004 for urban buses or 60% of annual production of urban buses (100% by 01/01/2005); in that case, manufacturers must produce at least 60% observing PROCONVE P5 for the non-urban bus HD annual production
(2) 1.1.2005 for micro-buses
(3) 1.1.2005 40% of production/year of HD (except urban bus and micro-bus) per manufacturer
(4) diesel vehicles without catalysts or particulate filters can be tested over ESC cycle only
(5) For engines of less than 0.75 dm^3 swept volume per cylinder and a rated power speed of more than 3000 rpm
(6) PROCONVE P6 standards were never implemented, P5 standards remain in effect through the end of 2011

Emissions Standards: Brazil
Nonroad Diesel Engines

In July 2011, the Conselho Nacional do Meio Ambiente (CONAMA) adopted Resolution 433/2011 limiting exhaust emissions and noise from new construction and farm machinery. Referred to as PROCONVE MAR-I, it is the first legislation to regulate emissions from nonroad mobile machinery in Brazil. It sets limits equivalent to USA Tier III and EU Stage III A for nonroad diesel engine emissions.

MAR-I emission limits are phased in from 2015 to 2019. The implementation dates depend on the power category and type of machinery (construction or farm), as shown in Table 1. Noise emission limits apply from 2015 for certain types of construction machinery with engines rated below 500 kW.

Table 1
MAR-I Emission Standards for Nonroad Engines

Rated Power	Date		CO	NO_x+HC	PM
kW	Construction	Farming	g/kWh		
130 ≤ P ≤ 560	2015.01	2017.01	3.5	4.0	0.2
75 ≤ P < 130	2015.01	2017.01	5.0	4.0	0.3
37 ≤ P < 75	2015.01	2019.01	5.0	4.7	0.4
19 ≤ P < 37	2017.01	2019.01	5.5	7.5	0.6

Emissions are measured in accordance with ISO 8178-1.

Emissions Standards: Chile
On-Road Vehicles And Engines

Background

Chilean emission standards for vehicles and engines are adopted by the Ministerio de Transportes y Telecomunicaciones (MTT) in cooperation with the Ministerio del Medio Ambiente (MMA).

Emission standards for highway vehicles, light- and heavy-duty, have been in place since the early 1990's. While the standards are based on US and EU emission regulations, they are not necessarily equivalent. Dual standards often exist, allowing new engines to meet either US or EU standards. No durability or on-board diagnostic (OBD) requirements are indicated in Chile's emission standards. Some OBD requirements are expected to be introduced after 2011.

The emission limits are based on the date that application is first made to register the vehicle in the national vehicle registry and the geographic region in which it operates. Application date for registration as opposed to vehicle model year is used presumably to control emissions from imported used vehicles. To legally operate an on-road vehicle in Chile, a colored sticker must be attached to the vehicle. The color of the sticker determines what region of the country a vehicle may operate in. Rules for issuing stickers depend on the vehicle class.

Due to more severe pollution problems, many vehicle emission standards for the Santiago Metropolitan Region (RM)

are more stringent and/or introduced earlier that those for the rest of the country. A decree issued in 2010 *[D.S. N° 66/10]* requires a number of programs to be established in the Santiago Metropolitan Region by 2011 to accelerate the uptake of cleaner vehicles. These programs include the implementation of a Low Emission Zone for heavy vehicles and a voluntary truck scrappage program.

Table 1
Emission Standards for Light-Duty Vehicles (1992-2006), g/km

Category	Date	CO	HC	NO_x	PM*
Light-Duty Vehicles GVWR < 2700 kg					
Passenger Cars	1992.09 (RM, V & VI) 1994.09 (National)	2.11	0.25	0.62	0.125
Light-Duty Trucks	1992.09 (RM, V & VI)	6.2	0.50	1.43	0.16
	1998.09 (RM) 2006.05 (National)	6.2	0.50	0.75	0.16
Medium-Duty Vehicles 2700 ≤ GVW < 3860 kg					
Type 1, LVW < 1700 kg	1995.09 (RM, V & VI)	6.2	0.50	1.43	0.16
	1998.09 (RM) 2006.05 (National)	6.2	0.50	0.75	0.16
Type 2, LVW ≥ 1700 kg	1995.09 (RM, V & VI)	6.2	0.50	1.43	0.31
	1998.09 (RM) 2006.05 (National)	6.2	0.50	1.10	0.08

* PM limits applicable to diesel vehicles only

Light-Duty Vehicles

The emission standards for light-duty (GVWR < 2700 kg) and medium-duty (2700 ≤ GVWR < 3860 kg) vehicles apply to 1994 model year and newer vehicles *[D.S. N° 211/1991 and D.S. N° 54/1994]*. Light-duty vehicles include passenger cars and light light-duty trucks. Medium-duty vehicles are heavy light-duty trucks.

Early emission standards for passenger cars and light trucks, which were based on US 1984 regulations, are shown in Table 1. These standards first applied in the Santiago Metropolitan Region and in the continental parts of Region V and Region VI. The test cycle was the US FTP 75.

More recent emission standards are summarized in Table 2.1 and Table 2.2 for diesel fueled vehicles and in Table 3.1 and Table 3.2 for gasoline, CNG and LPG fueled vehicles. Standards for light- and medium-duty vehicles reflecting US Tier 1 and Euro 3 standards came into effect in 2005 for RM and 2006 nationally. For light-duty diesel fueled vehicles operating in RM, standards based on California Tier 1 and Euro 4 were adopted for 2006/2007 and will be tightened to EPA Tier 2 Bin 5/Euro 5 levels in 2011. EPA Tier 2 Bin 8/Euro 4 based standards for light-duty vehicles with a spark ignition engine operating in RM will apply in 2011. For medium-duty spark ignition and diesel fueled vehicles operating in RM, standards based on EPA Tier 1 Bin 8 and Euro 4 levels will come into effect in 2011. For medium-duty diesel fueled vehicles, these will be tightened to EPA Tier 2 Bin 5/Euro 5 in 2012. The US based standards are numerically equal to the intermediate life (5 year/50,000 mile) EPA or California limits.

New gasoline fueled vehicles must also meet an evaporative emission limit of 2 g/test (SHED).

In-use vehicles. Inspection and Maintenance tests are carried out with a two speed idle test. In-use light-duty, medium-duty spark-ignition and heavy-duty gasoline fueled vehicles

Table 2.1
Emission Standards for Diesel Fueled Light-Duty Vehicles, g/km
Alternative 1: US Based Standards

Category	Date	CO	HCHO*	NMHC†	NO_x	PM	Reference
Light-Duty Vehicles GVWR < 2700 kg							
Passenger Cars ≤ 12 passengers	2005.01 (RM) 2006.09 (National)	2.11		0.16[a]	0.62	0.05	EPA Tier 1, Intermediate life
LDT Type 1, LVW ≤ 1700 kg		2.11		0.16	0.62	0.05	
LDT Type 2, LVW > 1700 kg		2.74		0.20	0.61	0.05	
Passenger Cars ≤ 12 passengers	2006.03 (RM)	2.11		0.16	0.25	0.05	California Tier 1, Intermediate life
LDT Type 1, LVW ≤ 1700 kg		2.11		0.16	0.25	0.05	
LDT Type 2, LVW > 1700 kg		2.74		0.20	0.44	0.05	
Passenger Cars ≤ 12 passengers	2011.09 (RM)	2.11	9.32	0.047	0.031	0.0062	EPA Tier 2 Bin 5, Intermediate life
LDT Type 1, LVW ≤ 1700 kg		2.11	9.32	0.047	0.031	0.0062	
LDT Type 2, LVW > 1700 kg		2.11	9.32	0.047	0.031	0.0062	
Medium-Duty Vehicles 2700 ≤ GVW < 3860 kg							
Type 1, 1700 kg < ALVW ≤ 2610 kg	2005.01 (RM) 2006.09 (National)	2.74		0.20	0.61	0.06	EPA Tier 1, Intermediate life
Type 2, ALVW ≥ 2610 kg		3.11		0.24	0.95	0.07	
Type 1, 1700 kg < ALVW ≤ 2610 kg	2011.04 (RM)	2.11	9.32	0.062	0.087	0.012	EPA Tier 2 Bin 8, Intermediate life
Type 2, ALVW ≥ 2610 kg		2.11	9.32	0.0062	0.087	0.012	
Type 1, 1700 kg < ALVW ≤ 2610 kg	2012.09 (RM)	2.11	9.32	0.0047	0.031	0.0062	EPA Tier 2 Bin 5, Intermediate life
Type 2, ALVW ≥ 2610 kg		2.11	9.32	0.0047	0.031	0.0062	

* mg/km
† NMOG in 2011/2012 standards
a - THC limit of 0.25 g/km is also applicable.

Table 2.2
Emission Standards for Diesel Fueled Light-Duty Vehicles, g/km
Alternative 2: EU Based Standards

Category	Date	CO	NO_x+HC	NO_x	PM	Reference
Light-Duty Vehicles GVWR < 2700 kg						
Passenger Cars	2005.01 (RM) 2006.09 (National)	0.64	0.56	0.50	0.05	Euro 3
LDT Class 1, RM ≤ 1305 kg		0.64	0.56	0.50	0.05	
LDT Class 2, 1305 kg < RM ≤1760 kg		0.80	0.72	0.65	0.07	
LDT Class 3, RM > 1760 kg		0.95	0.86	0.78	0.10	
Passenger Cars	2006.03[a] (RM)	0.50	0.30	0.25	0.025	Euro 4
LDT Class 1, RM ≤ 1305 kg		0.50	0.30	0.25	0.025	
LDT Class 2, 1305 kg < RM ≤1760 kg	2007.03 (RM)	0.63	0.39	0.33	0.04	
LDT Class 3, RM > 1760 kg		0.74	0.46	0.39	0.06	
Passenger Cars	2011.09 (RM)	0.500	0.230	0.180	0.005	Euro 5
LDT Class 1, RM ≤ 1305 kg		0.500	0.230	0.180	0.005	
LDT Class 2, 1305 kg < RM ≤1760 kg	2012.09 (RM)	0.500	0.295	0.235	0.005	
LDT Class 3, RM > 1760 kg		0.500	0.350	0.280	0.005	
Medium-Duty Vehicles 2700 ≤ GVW < 3860 kg						
MDT Class 1, RM ≤1305	2005.01 (RM) 2006.09 (National)	0.64	0.56	0.50	0.05	Euro 3
MDT Class 2, 1305 < RM ≤ 1760 kg		0.80	0.72	0.65	0.07	
MDT Class 3, RM > 1760 kg		0.95	0.86	0.78	0.10	
MDT Class 1, RM ≤1305	2011.04 (RM)	0.50	0.30	0.25	0.025	Euro 4
MDT Class 2, 1305 < RM ≤ 1760 kg		0.63	0.39	0.33	0.04	
MDT Class 3, RM > 1760 kg		0.74	0.46	0.39	0.06	
MDT Class 1, RM ≤1305	2012.09 (RM)	0.50	0.230	0.180	0.005	Euro 5
MDT Class 2, 1305 < RM ≤ 1760 kg		0.63	0.295	0.235	0.005	
MDT Class 3, RM > 1760 kg		0.74	0.350	0.280	0.005	
a - 2007.03 for passenger cars with GVWR > 2500 kg						

Table 3.1
Emission Standards for Gasoline, CNG and LPG Fueled Light-Duty Vehicles, g/km
Alternative 1: US Based Standards

Category	Date	CO	HCHO*	HC	NMHC†	NO_x	Reference
Light-Duty Vehicles GVWR < 2700 kg							
Passenger Cars ≤ 12 passengers	2005.01 (RM) 2006.09 (National)	2.11		0.25	0.16	0.25	EPA Tier 1, Intermediate life
LDT Type 1, LVW ≤ 1700		2.11		0.25	0.16	0.25	
LDT Type 2, LVW > 1700		2.74		0.25	0.20	0.44	
Passenger Cars ≤ 12 passengers	2011.04 (RM)	2.11	9.32		0.062	0.087	EPA Tier 2 Bin 8, Intermediate life
LDT Type 1, LVW ≤ 1700		2.11	9.32		0.062	0.087	
LDT Type 2, LVW > 1700		2.11	9.32		0.062	0.087	
Medium-Duty Vehicles 2700 ≤ GVW < 3860 kg							
Type 1, 1700 kg < ALVW ≤ 2610 kg	2005.01 (RM) 2006.09 (National)	2.70			0.20	0.44	EPA Tier 1, Intermediate life
Type 2, ALVW ≥ 2610 kg		3.11			0.24	0.68	
Type 1, 1700 kg < ALVW ≤ 2610 kg	2011.04 (RM)	2.11	9.32		0.062	0.087	EPA Tier 2 Bin 8, Intermediate life
Type 2, ALVW ≥ 2610 kg		2.11	9.32		0.062	0.087	
* mg/km † NMOG in 2011/2012 standards							

have to meet I/M maximum limits of 0.5% CO and 100 ppm HC. Light-duty SI vehicles must also meet a minimum limit of 6% CO_2 + CO. Light-duty diesels must show no visible smoke. Medium-duty and heavy-duty diesels must pass filter smoke number and opacity tests with the engine under load and during a snap-acceleration test. An in-use opacity limit for vehicles equipped with particulate filters is set at 0.24 m^{-1} maximum *[D.S. N° 66/10]*. Urban buses have also the following in-use emission limits *[D.S. N° 130/02]*:

- Smoke opacity < 4%, k = 1.0 1/m for diesel engines
- CO < 0.5%, THC < 100 ppm for gaseous fuel and gasoline engines

Trucks And Buses

Emission standards for heavy-duty truck and bus engines *[D.S. N° 55/1994]* are listed in Table 4. Early standards applied to vehicles operating in the Santiago Metropolitan Region (RM) and Region IV to X. Nationwide standards took effect in 2006. In cases where dual standards exist — EU-based and US-based — engines are tested on the respective EU or US test cycles, as indicated.

Starting with heavy-duty vehicles first registered January 2012 and later and operating in the Metropolitan Region, PM emissions are limited to Euro IV/US 2007 levels while NO_x limits for these vehicles remain at Euro III/US 1998 levels. In addition

Table 3.2 Emission Standards for Gasoline, CNG and LPG Fueled Light-Duty Vehicles, g/km **Alternative 2:** EU Based Standards					
Category	**Date**	**CO**	**HC**	**NO_x**	**Reference**
Light-Duty Vehicles GVWR < 2700 kg					
Passenger Cars	2005.01 (RM) 2006.09 (National)	2.3	0.20	0.15	Euro 3
LDT Class 1, RM ≤ 1305 kg		2.3	0.20	0.15	
LDT Class 2, 1305 < RM ≤ 1760 kg		4.17	0.25	0.18	
LDT Class 3, RM > 1760 kg		5.22	0.29	0.21	
Passenger Cars	2011.04 (RM)	1.00	0.10	0.08	Euro 4
LDT Class 1, RM ≤ 1305 kg		1.00	0.10	0.08	
LDT Class 2, 1305 < RM ≤ 1760 kg		1.81	0.13	0.10	
LDT Class 3, RM > 1760 kg		2.27	0.16	0.11	
Medium-Duty Vehicles 2700 ≤ GVW < 3860 kg					
MDT Class 1, RM ≤ 1305 kg	2005.01 (RM) 2006.09 (National)	2.3	0.20	0.15	Euro 3
MDT Class 2, 1305 kg < RM ≤ 1760 kg		4.17	0.25	0.18	
MDT Class 3, RM > 1760 kg		5.22	0.29	0.21	
Medium-Duty Vehicles 2700 ≤ GVW < 3860 kg					
MDT Class 1, RM ≤ 1305 kg	2011.04 (RM)	1.00	0.10	0.08	Euro 4
MDT Class 2, 1305 kg < RM ≤ 1760 kg		1.81	0.13	0.10	
MDT Class 3, RM > 1760 kg		2.27	0.16	0.11	

to OEM vehicles produced to meet the 2012 PM requirements, the limit can also be met by engines originally certified to PM emissions higher than the levels shown if they have been fitted with a diesel particulate filter carrying an approval by the Swiss Federal Office for the Environment (FOEN) or California ARB Level 3 verification and if the engine's certification PM emissions multiplied by (1 - filter efficiency/100) does not exceed the limits shown. It should be reinforced that this is not a retrofit requirement for vehicles first registered prior to 2012 but a compliance option for those first registered after January 2012.

Emission standards for urban buses operating in certain parts of the Santiago Metropolitan Region (Santiago Province and the municipalities of San Bernardo and Puente Alto) are more stringent than those listed in Table 4. These are listed in Table 5. The most recent 2002 limits *[D.S. N° 130/02]* are equivalent to Euro III/US 1998 standards. Urban buses first registered in September 2012 or later for use in this region must be equipped with a factory installed OEM diesel particulate filter to ensure emissions do not exceed the limits equivalent to Euro IV or US 2004 NMHC+NO_x/US 2007 PM *[D.S. N° 66/10]*.

Table 4 Emission Standards for Heavy-Duty Engines, GVW ≥ 3860 kg							
Date	**CO**	**HC**	**NO_x**	**PM**	**Unit**	**Test**	**Reference**
Diesel							
1994.09 (RM & IV-X)[1]	4.5	1.1	8.0	0.36[a]	g/kWh	ECE R-49	Euro I
	15.5	1.3	6.0	0.35	g/bhp-hr	US FTP	US 1991
1998.09 (RM & IV-X) 2006.05 (National)	4.0	1.1	7.0	0.15	g/kWh	ECE R-49	Euro II
	15.5	1.3	5.0	0.10	g/bhp-hr	US FTP	US 1994
2006.10 (RM & IV-X)[2]	2.1	0.66	5.0	0.10 (0.13*)	g/kWh	ESC	Euro III
	5.45	0.78	5.0	0.16 (0.21*)		ETC	
	15.5	1.3	4.0	0.10	g/bhp-hr	US FTP	US 1998
2012.01 (RM)	2.1	0.66	5.0	0.02	g/kWh	ESC	Euro III/Euro IV PM
	5.45	0.78	5.0	0.03		ETC	
	15.5	1.3	4.0	0.01	g/bhp-hr	US FTP	US 1998/US2007 PM
Gasoline							
1994.09	37.1	1.9	5.0	-	g/bhp-hr	US FTP	
Gaseous Fuels							
2004.01 (RM)	5.45	0.78[b]	5.0		g/kWh	ETC	
	15.5	1.3[c]	4.0	0.10	g/bhp-hr	US FTP	

* for engines of less than 0.75 dm^3 swept volume per cylinder and a rated power speed of more than 3000 min^{-1}
1 - Regions where standard took effect on date indicated
2 - ETC testing and emission limits apply only to diesel engines with advanced aftertreatment, e.g., with particulate filters and/or NO_x catalysts
a - 0.612 g/kWh for engines < 85 kW
b - NMHC for natural gas engines; natural gas engines must also meet a CH_4 limit of 1.6 g/kWh
c - 1.2 g/bhp-hr NMHC for natural gas engines

Table 5 Emission Standards for Urban Buses in Metropolitan Region							
Date	**CO**	**HC**	**NO_x**	**PM**	**Unit**	**Test**	**Reference**
Diesel							
1993.09	4.5	1.1	8.0	0.36[a]	g/kWh	ECE R-49	Euro I
	15.5	1.3	6.0	0.25	g/bhp-hr	US FTP	US 1991
1996.09	4.0	1.1	7.0	0.15	g/kWh	ECE R-49	Euro II
	15.5	1.3	5.0	0.10	g/bhp-hr	US FTP	US 1994
2002.09†	2.1	0.66	5.0	0.10 (0.13*)	g/kWh	ESC	Euro III
	5.45	0.78	5.0	0.16 (0.21*)		ETC	
	15.5	1.3	4.0	0.05	g/bhp-hr	US FTP	US 1998
2012.09	1.50	0.46	3.5	0.02	g/kWh	ESC	Euro IV
	4.0	0.55	3.5	0.03		ETC	
	15.5	2.4[d]		0.01	g/bhp-hr	US FTP	US 2004/US 2007 PM
Gasoline							
1993.09	37.1	1.9	5.0	-	g/bhp-hr	US FTP	
Gaseous Fuels							
2002.09	5.45	0.78[b]	5.0	-	g/kWh	ETC	Euro III
	15.5	1.3[c]	4.0	0.05	g/bhp-hr	US FTP	US 1998

* for engines of less than 0.75 dm^3 swept volume per cylinder and a rated power speed of more than 3000 min^{-1}
† for Euro III diesel vehicles whose first application for registration is made before 2006.03, ETC testing and emission limits apply only to diesel engines with advanced aftertreatment, e.g., with particulate filters and/or NO_x catalysts. ESC and ETC testing applies to all diesel vehicles whose first application for registration is made 2006.03 or later.
a - 0.612 g/kWh for engines < 85 kW
b - NMHC for natural gas engines; natural gas engines must also meet a CH_4 limit of 1.6 g/kWh
c - 1.2 g/bhp-hr NMHC for natural gas engines
d - NMHC+NO_x. An limit of 2.5 g/bhp-hr applies if NMHC do not exceed 0.5 g/bhp-hr

Gasoline and gas fueled trucks and buses have also an evaporative emission limit of 4 g per test.

Acknowledgement: *This article based in part on information submitted by Marcelo M. Guerrero of ENAP.*

Emissions Standards: Chile
Generator Sets

Generator set emissions for the Santiago Metropolitan Region are limited by the regulations defining particulate matter (PM) limits for stationary sources, Table 1. The limits apply to generator sets rated at 20 kW or more electrical output and must be met at rated conditions.

Table 1 Emission Limits for Generator Sets in the Santiago Metropolitan Region			
Nominal Power, P	**PM Limit**	**Application**	**Frequency of Certification**
P < 300 kW	56 mg/Nm^3	Continuous / Prime Power	Every 3 years
		Emergency	Certification not required
P ≥ 300 kW	112 mg/Nm^3	Continuous / Prime Power	Every 1 year
		Emergency	Certification required only once

In situations of poor ambient air quality, sources with PM emissions greater than 32 mg/Nm^3 (28 mg/Nm^3 if air quality is exceptionally bad) are not allowed to operate.

In November 2006, a draft regulation was published in Chile's national gazette that would set emission limits in the Santiago Metropolitan Region for new and existing stand-by and emergency electricity generator sets powered by internal combustion engines. The regulation would be applicable to units rated at 20 kW or more electrical output. The proposed limits are outlined below.

Emissions would be measured at rated conditions, converted to standard conditions (25°C and 1 atm) and corrected to 5% O_2 by volume.

Compliance for existing generators would have to be demonstrated within 1 year of the date that the regulation enters into force. Compliance for new generators would need to be demonstrated by their operators within 60 days of registration with the regional health authority.

Table 2 Proposed Emission Standards for Generator Sets, mg/Nm³						
	Application	**Nominal Power, P**	**PM**	**NO_x**	**CO**	**THC**
Existing Generators	Prime Power	20 kW ≤ P < 300 kW	45	5,000	600	400
		P ≥ 300 kW	5	5,000	600	400
	Emergency	P ≥ 150 kW	180	-	-	-
New Generators	Prime Power	20 kW ≤ P < 300 kW	45	2,900	600	400
		P ≥ 300 kW	5	2,900	600	400
	Emergency	P ≥ 20 kW	75	2,900	600	400

Acknowledgement: *This article based in part on information submitted by Marcelo M. Guerrero of ENAP.*

Emissions Standards: Peru
On-Road Vehicles And Engines

Maximum permissible emission limits for existing vehicles, new imported or domestically assembled vehicles and used imported vehicles have been established by decree D.S. N° 047-2001-MTC:

- Since January 1, 2003 all new light-duty vehicles in Peru have been required to meet either US or EU emission standards (Euro 2 or US Tier 0).

New heavy-duty have been required to meet Euro II.

- Starting in 2007, new light-duty vehicles must meet Euro 3 requirements and new heavy-duty vehicles must meet Euro III requirements.

Peruvian emission requirements for light-, medium- and heavy-duty vehicles are summarized in the following tables.

Table 1 Emission Requirements for Light-Duty Vehicles				
Year	**Option 1***		**Option 2†**	
	Standard	Regulation	Standard	Regulation
2003	Euro 2	94/12/EC	US Tier 0	US 83 LDV
2007	Euro 3	98/69/EC (A)		
* New passenger vehicles GVWR ≤ 2500 kg or ≤ 6 seats † Passenger vehicles ≤ 12 seats				

Table 2 Emission Requirements for Medium-Duty Vehicles				
Year	**Option 1***		**Option 2†**	
	Standard	Regulation	Standard	Regulation
2003	Euro 2	96/69/EC	US Tier 0	US 87 LDT
2007	Euro 3	98/69/EC (A)		
* New passenger vehicles GVWR > 2500 kg or > 6 seats; commercial vehicles < 3500 kg † Vans and light-duty trucks < 3864 kg; new passenger vehicles > 12 seats				

Table 3 Emission Requirements for Heavy-Duty Vehicles*			
Year	**Standard**	**Cycle**	**Regulation**
2003	Euro II	13 mode	96/1/EC
2007	Euro III	ESC + ELR	88/77/EEC (99/96/EC)
* New passenger vehicles and commercial vehicles > 3500 kg			

IMO Marine Engine Regulations

Background

International Maritime Organization (IMO) is an agency of the United Nations which has been formed to promote maritime safety. It was formally established by an international conference in Geneva in 1948, and became active in 1958 when the IMO Convention entered into force (the original name was the Inter-Governmental Maritime Consultative Organization, or IMCO, but the name was changed in 1982 to IMO). IMO currently groups 167 Member States and 3 Associate Members.

IMO ship pollution rules are contained in the "International Convention on the Prevention of Pollution from Ships", known as MARPOL 73/78. On 27 September 1997, the MARPOL Convention has been amended by the "1997 Protocol", which includes Annex VI titled "Regulations for the Prevention of Air Pollution from Ships". MARPOL Annex VI sets limits on NO_x and SO_x emissions from ship exhausts, and prohibits deliberate emissions of ozone depleting substances.

The IMO emission standards are commonly referred to as Tier I/II/III standards. The Tier I standards were defined in the 1997 version of Annex VI, while the Tier II/III standards were introduced by Annex VI amendments adopted in 2008, as follows:

- 1997 Protocol (Tier I)—The "1997 Protocol" to MARPOL, which includes Annex VI, becomes effective 12 months after being accepted by 15 States with not less than 50% of world merchant shipping tonnage. On 18 May 2004, Samoa deposited its ratification as the 15th State (joining Bahamas, Bangladesh, Barbados, Denmark, Germany, Greece, Liberia, Marshal Islands, Norway, Panama, Singapore, Spain, Sweden, and Vanuatu). At that date, Annex VI was ratified by States with 54.57% of world merchant shipping tonnage.

  Accordingly, Annex VI entered into force on 19 May 2005. It applies retroactively to new engines greater than 130 kW *installed on vessels constructed on or after January 1, 2000,* or which undergo a major conversion after that date. The regulation also applies to fixed and floating rigs and to drilling platforms (except for emissions associated directly with exploration and/or handling of sea-bed minerals). In anticipation of the Annex VI ratification, most marine engine manufacturers have been building engines compliant with the above standards since 2000.

- 2008 Amendments (Tier II/III) — Annex VI amendments adopted in October 2008 introduced (1) new fuel quality requirements beginning from July 2010, (2) Tier II and III NO_x emission standards for new engines, and (3) Tier I NO_x requirements for existing pre-2000 engines.

  The revised Annex VI enters into force on 1 July 2010. By October 2008, Annex VI was ratified by 53 countries (including the Unites States), representing 81.88% of tonnage.

Emission Control Areas. Two sets of emission and fuel quality requirements are defined by Annex VI: (1) global requirements, and (2) more stringent requirements applicable to ships in Emission Control Areas (ECA). An Emission Control Area can be designated for SO_x and PM, or NO_x, or all three types of emissions from ships, subject to a proposal from a Party to Annex VI.

Existing Emission Control Areas include:

- Baltic Sea (SO_x, adopted: 1997 / entered into force: 2005)
- North Sea (SO_x, 2005/2006)
- North American ECA, including most of US and Canadian coast (NO_x & SO_x, 2010/2012).
- US Caribbean ECA, including Puerto Rico and the US Virgin Islands (NO_x & SO_x, 2011/2014).

Greenhouse Gas Emissions. 2011 Amendments to MARPOL Annex VI introduced mandatory measures to reduce emissions of greenhouse gases (GHG). The Amendments added a new Chapter 4 to Annex VI on "Regulations on energy efficiency for ships".

NO_x Emission Standards

NO_x emission limits are set for diesel engines depending on the engine maximum operating speed (n, rpm), as shown in Table 1 and presented graphically in Figure 1. Tier I and Tier II limits are global, while the Tier III standards apply only in NO_x Emission Control Areas.

Table 1. MARPOL Annex VI NO_x Emission Limits

Tier	Date	NO_x Limit, g/kWh		
		n < 130	130 ≤ n < 2000	n ≥ 2000
Tier I	2000	17.0	$45 \cdot n^{-0.2}$	9.8
Tier II	2011	14.4	$44 \cdot n^{-0.23}$	7.7
Tier III	2016†	3.4	$9 \cdot n^{-0.2}$	1.96

† In NO_x Emission Control Areas (Tier II standards apply outside ECAs).

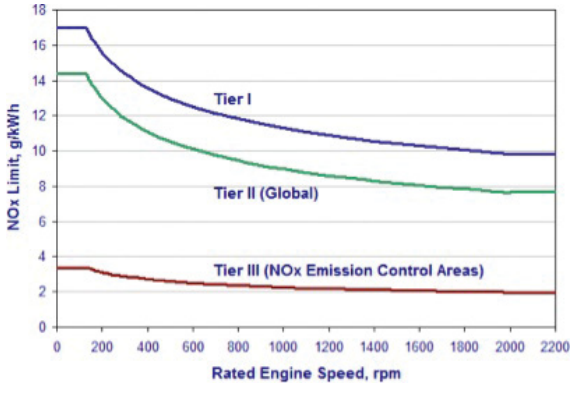

Figure 1. MARPOL Annex VI NO_x Emission Limits

Tier II standards are expected to be met by combustion process optimization. The parameters examined by engine manufacturers include fuel injection timing, pressure, and rate (rate shaping), fuel nozzle flow area, exhaust valve timing, and cylinder compression volume.

Tier III standards are expected to require dedicated NO_x emission control technologies such as various forms of water induction into the combustion process (with fuel, scavenging air, or in-cylinder), exhaust gas recirculation, or selective catalytic reduction.

Pre-2000 Engines. Under the 2008 Annex VI amendments, Tier I standards become applicable to existing engines installed on ships built between 1st January 1990 to 31st December 1999, with a displacement ≥ 90 liters per cylinder and rated output ≥ 5000 kW, subject to availability of approved engine upgrade kit.

Testing. Engine emissions are tested on various ISO 8178 cycles (E2, E3 cycles for various types of propulsion engines, D2 for constant speed auxiliary engines, C1 for variable speed and load auxiliary engines).

Addition of *not-to-exceed (NTE)* testing requirements to the Tier III standards is being debated. NTE limits with a multiplier of 1.5 would be applicable to NO_x emissions at any individual load point in the E2/E3 cycle.

Engines are tested using distillate diesel fuels, even though residual fuels are usually used in real life operation.

Further technical details pertaining to NO_x emissions, such as emission control methods, are included in the mandatory "NO_x Technical Code", which has been adopted under the cover of "Resolution 2".

Sulfur Content of Fuel

Annex VI regulations include caps on sulfur content of fuel oil as a measure to control SO_x emissions and, indirectly, PM emissions (there are no explicit PM emission limits). Special fuel quality provisions exist for SO_x Emission Control Areas (SO_x ECA or SECA). The sulfur limits and implementation dates are listed in Table 2 and illustrated in Figure 2.

Table 2. MARPOL Annex VI Fuel Sulfur Limits

Date	Sulfur Limit in Fuel (% m/m)	
	SO_x ECA	Global
2000	1.5%	4.5%
2010.07	1.0%	
2012		3.5%
2015	0.1%	
2020[a]		0.5%

a - alternative date is 2025, to be decided by a review in 2018

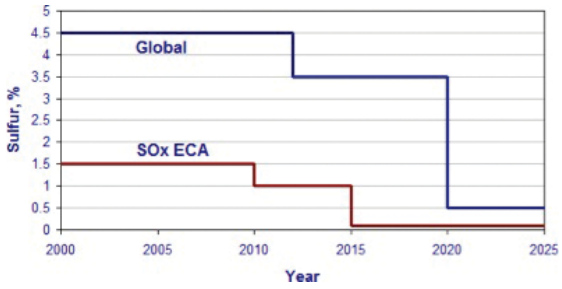

Figure 2. MARPOL Annex VI Fuel Sulfur Limits

Heavy fuel oil (HFO) is allowed provided it meets the applicable sulfur limit (i.e., there is no mandate to use distillate fuels).

Alternative measures are also allowed (in the SO_x ECAs and globally) to reduce sulfur emissions, such as through the use of scrubbers. For example, in lieu of using the 1.5% S fuel in SO_x ECAs, ships can fit an exhaust gas cleaning system or use any other technological method to limit SO_x emissions to ≤ 6 g/kWh (as SO_2).

Greenhouse Gas Emissions

MARPOL Annex VI, Chapter 4 introduces two mandatory mechanisms intended to ensure an energy efficiency standard for ships: (1) the Energy Efficiency Design Index (EEDI), for new ships, and (2) the Ship Energy Efficiency Management Plan (SEEMP) for all ships.

- The EEDI is a performance-based mechanism that requires a certain minimum energy efficiency in new ships. Ship designers and builders are free to choose the technologies to satisfy the EEDI requirements in a specific ship design.

- The SEEMP establishes a mechanism for operators to improve the energy efficiency of ships.

The regulations apply to all ships of and above 400 gross tonnage and enter into force from 1 January 2013. Flexibilities exist in the initial period of up to six and a half years after the entry into force, when the IMO may waive the requirement to comply with the EEDI for certain new ships, such as those that are already under construction.

Other Provisions

Ozone Depleting Substances. Annex VI prohibits deliberate emissions of ozone depleting substances, which include halons and chlorofluorocarbons (CFCs). New installations containing ozone-depleting substances are prohibited on all ships. But new installations containing hydro-chlorofluorocarbons (HCFCs) are permitted until 1 January 2020.

Annex VI also prohibits the incineration on board ships of certain products, such as contaminated packaging materials and polychlorinated biphenyls (PCBs).

Compliance. Compliance with the provisions of Annex VI is determined by periodic inspections and surveys. Upon passing the surveys, the ship is issued an "International Air Pollution Prevention Certificate", which is valid for up to 5 years. Under the "NO_x Technical Code", the ship operator (not the engine manufacturer) is responsible for in-use compliance.

This article based in part on information provided by Michael F. Pedersen of MAN Diesel A/S.

Emissions Standards: International
UIC Locomotive

Background

Emission standards for railway locomotives have been established by the International Union of Railways (Union Internationale des Chemins de fer, UIC), a Paris-based association of European railway companies. UIC issues technical *leaflets* on railway equipment and components, which are termed "standards" and are binding to member railways. Emission standards for rail locomotives are specified in UIC Leaflet 624, published in April 2002 and titled "Exhaust emission tests for diesel traction engines."

The UIC emission standards apply to diesel engines for railway traction, with the exception of engines for special locomotives (e.g., refinery or mine locomotives) and traction engines with an output of less than 100 kW. The standards apply to all new engines used in new vehicles or for repowering of existing locomotives.

Emission Standards

The UIC locomotive emission standards are listed in the following table. The test method is ISO 8178, cycle F.

Table 1
UIC Locomotive Emission Standards

Stage	Date	Power, P	Speed, n	CO	HC	NO_x	PM	Smoke
		kW	rpm	g/kWh				BSN
UIC I	up to 2002.12.31			3	0.8	12	-	1.6-2.5[a]
UIC II	2003.1.1	P ≤ 560		2.5	0.6	6.0	0.25	
		P > 560	n > 1000	3	0.8	9.5	0.25[b]	
			n ≤ 1000	3	0.8	9.9	0.25[b]	

a - Bosch smoke number (BSN) = 1.6 for engines with an air throughput of above 1 kg/s; BSN = 2.5 for engines below 0.2 kg/s; linear BSN interpolation applies between these two values.
b - For engines above 2200 kW, a PM emission of 0.5 g/kWh is accepted on an exceptional basis until 2004.12.31.

The UIC Stage III standards are harmonized with the EU Stage IIIA standards for nonroad engines *[Directive 97/68/EC]*.